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THE GOLDMINE OF KANDAHAR.
AURIFEROUS VEIN MARKED +++

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rises to peaks of about 8,500 feet, with passes (Kojak) of about 7,500 feet in height.

Beyond that the road traverses the great plains of the confluents of the Dori river, about 4,000 feet over sea-level, with insignificant rises and *kotals;* but the whole is an inclined plain with a slight fall towards Kandahar, which itself is only about 3,350 feet above the sea.

The road between Kandahar and Girishk on the Helmand is similar and also descending. Out of that plain rises abruptly the Shah Maksud range to heights of 8,000 to 11,000 feet with high passes leading northwards into the Tirin and other valleys.

Division into three distinct geological areas.—The country which came under my observation in Biluchistan and Southern Afghanistan can easily be grouped into three geologically and structurally distinct areas; namely—

1. *The Brahuik area of Biluchistan,* coinciding with the limestone facies of the older tertiaries.

2. *The Pishin valley* with its eastern and western ranges (Ghaziaband and Kojak), falling in with the sandstone and shales (flysch) facies of the eocene group.

3. *The Kandahar and Shah Maksud ranges,* all formed of cretaceous limestone and eruptive rocks of the same age.

1. *The Brahuik area.*—Entering the Bolan pass from India, one has to traverse a number of more or less parallel ridges, with tolerably easy passes leading over them. Dislocations mostly vertical to the strike of the ranges have prepared the course (in the first instance) for rivers, as for example the Bolan, the Nari, etc.

Very little is known about the course of the numerous ridges, except that they form a connecting link between the Hala or Hara mountains of Southern Biluchistan and the more northern Suliman range; the most important passes into Southern Afghanistan lead over this part of the range, which Pottinger has called the Brahuik hills. Some points (as for example the Takatu near Quetta) reach a height of

12,000 feet, but the average height is from 4,000 to 7,000 feet above the sea, fringed by ranges much below that along the Indian frontier.

Geology of the area.

The geological structure, in spite of the numerous contortions and partial dislocations, is extremely simple. The western ridges and, at the same time, the highest ones, along which line is found the Takatu hill, are made up of cretaceous rocks, folded and raised into dome-shaped masses, showing a great deal of local disturbance. East of the highest part of the Bolan pass, near Sir-i-Bolan and between that line and Kohundilani, eocene rocks of the nummulitic limestone facies prevail, with a lower coal-bearing series (Ranikot beds). These beds have also undergone great lateral pressure, and are folded, raised into dome-shaped masses, and in places inverted, making the detailed examination a work of considerable difficulty. Eastward of this ground, and deposited quite unconformably against the upraised beds of the eocene series, the middle and upper tertiary rocks (Gaj and Manchhar groups) form several ridges of considerable height, which from afar off can easily be distinguished from the eocene limestone hills on the westward, presenting a totally different physical aspect and outline. I have endeavoured to show this character in profile 1, of Pl. I, which represents a camera sketch of the outer (Manchhar) hills near Pir Chowki. The nummulitic limestone cliffs are seen beyond as white peaks.

Owing to the disturbed condition of the country I was only able to make this one traverse across the ranges of the Bolan; but I believe, from the information afforded me by gentlemen who have passed over the Hurnai route from Sibi to Quetta, that the structure which I observed in the Bolan holds good there also. The entrance to that pass I know myself, and I have given a profile (2 Pl. I), of the fold of Manchhars forming the hills near Nari gorge. It is interesting to compare this section with those given by Messrs. Blanford and Ball[1] from the regions south and north of my traverse.

[1] W. T. Blanford—"The Geology of Western Sind," Mem. Vol. XVII, Pt. I.

V. Ball—"Geological Notes made on a visit to the coal recently discovered in the country of the Luni Pathans," Rec. Vol. VII.

Correspondence with Sind sections.

I found that in the main structural features the area of the Brahuik hills corresponds closely with the sections given by Mr. Blanford in his "Western Sind;" and had it been possible to devote more time to the examination of the Bolan, no doubt all his sub-divisions of the tertiary series could have been identified. As it is, I am quite certain that the hills between the Indus plain and the Quetta valley are simply a continuation of the Kirthar range, and that very little difference will be found between the two sections.

Mr. Ball's section from Saki Sarwar to the Chamarlang valley discloses similar geological features of an outer (eastern) belt of sandstones of Síwalik type resting on shales, sandstones, and clays, of a character closely resembling the description given of the Gáj group of Sind. The eocene group consists evidently of the same members as further south, namely, a lower coal-bearing and an upper nummulitic series. It is, therefore, clearly indicated that the range of hills, which in turn bears the names of Suliman range, the Marri hills, Brahuik ranges, the Kirthar, and lastly, perhaps, the Hala range, all form links of one great chain, which presents a uniform geological structure.

Physical features.

2. *The Pishin Area.*—The often described Pishin valley is part of the drainage area of the Lora river, which scooped out its course in the trough formed by two parallel ranges, the eastern the Ghaziaband ridge, with a branch of the Brahuik hills, and the Kojak Amran range which is sent out from the little known Toba plateau in a south-westerly direction. The Toba plateau bounds the Pishin valley northwards, and sends numerous little rivulets into the Lora, which river eventually dies away in the sandy region south of Shorawak, which lies south-west of the extensive tract of low hills closing the Pishin plain on the south and amongst which the Lora river has formed for itself a tortuous course. I know this tract only near its northern margin; but from what I could gather from information received from other sources, the same geological features seem to prevail for a considerable distance. The Pishin valley is about 800 to

900 feet below that of Quetta, and is a plain of from 16 to 20 miles wide, very gently sloping from the bounding hill ranges towards the bed of the Lora.

Geology.

The formation of these parallel bounding hill ranges is due to the same causes which brought about the folding of the tertiary series of the Brahuik hills into narrow parallel ridges, that is, a great lateral pressure, which operated in late tertiary times, and probably is still in continuance.

With the exception of a strip of rocks of probably cretaceous origin near the east slope of the Kojak Amran range, all the rocks of this area are of tertiary age.

Eocene series.

Amongst them the eocene series is of special interest, as here differing completely from its form in the Brahuik hills. We have in these adjoining areas two distinct facies of the eocene deposits, closely corresponding in this two-fold character with what has been observed in other regions, presently to be touched upon. Roughly speaking, the series consists of sandstones, fine silky clay shales and subordinate argillaceous limestone beds, and deep red and bluish green-coloured clays overlaid by nummulitic limestone. No one who has seen the flysch rocks of Europe can help being struck by the great lithological resemblance between them and this Afghan tertiary group. It is, of course, possible that some of the lower of these flysch rocks comprise cretaceous beds, in the same way as the flysch of south-eastern Europe does; but I am unable to determine this point with certainty.

Its position between the cretaceous limestone on one side and the nummulitic limestone on the other makes it certain that this series is a heteropic development of the Ranikot group, which in the adjoining Brahuik hills performs such a conspicuous part.

The entire range, crossed by the Ghaziaband pass, separating the valleys of Quetta and Pishin, is evidently made up of this series, presenting a number of contortions of a very complicated nature. So also the Kojak Amran range is mainly composed of the flysch-like rocks of the eocene (see fig. 6). Rocks of the Gáj group, already found near the eastern

margin of the Brahuik hills, form all the lower hills skirting the eocene series on both sides of the Ghazíaband range, reach high up into the valley of the Kakar Lora, and form the extensive low hilly ground through which the lower Lora winds its way into the Shorawak district. The great plain of the Pishin valley is covered, in common with all the other great valleys of Southern Afghanistan, with post-tertiary deposits of great thickness, consisting generally of great masses of sand, clays and gravels, covered with a thick and *uniform* bed of breccia formed of pebbles and angular debris derived from the adjoining rocks, held together by a calcareous cement, which is covered up in some places by more recent alluvial sand and clays.

3. The Kandahar and Helmand area.—The west slope of the Kojak-Amran range forms, as far as I could ascertain, the boundary line between the flysch group of the eocene series and the different members of the cretaceous series. The structural aspect of this 3rd region, that is, the country between the Amran range and the river Helmand comprising the valleys of the Dori, the Tarnak, and the Argandab, is very simple. A plain, only slightly undulating, stretches away towards the Helmand, with but a small decrease in elevation, the difference in height being about 400 to 500 feet only. This plain is formed of the youngest of the tertiary deposits,—in places indeed only blown sand. Out of it at intervals crop up older rocks, mostly hippuritic limestone, the latter much altered in places by a granitic rock, which has shattered and riddled the limestone in all directions, and plays an important part in the composition of the hill ranges traversed between Chaman and the Helmand. Nearly all the passes leading from the Argandab into the Khakrez valley are in the granitic ridge, which forms as it were a long dyke in the hippuritic limestone of the district.

Granitic rock.

Basic eruptive rocks of various descriptions, all of which I have united in the map under the heading Trap, form the youngest members of the cretaceous series. They run as dykes and veins through the granitic rock and hippuritic

Traps.

limestone, and form huge sheets and spreads between the beds of the latter. It is near the contact of the trap with the limestone and of the latter with the granite that we find the auriferous quartz-veins and lead ores, the latter common in many parts of Afghanistan.

Such is the composition of the hill ranges dividing the Tarnak from the Dori and from the Argandab, and also of the Argandab-Khakrez range.

As far as I could judge from a hasty examination, the Shah Maksud range (pl. X) is made up of hippuritic limestone, altered in places and near the contact with the granitic rock to a crystalline marble; great spreads of trap occupy the base of the valleys and protrude from under the covering post-tertiary deposits. In fact the presence of the trap, nearly always at the base of these valleys, may be explained in that this rock has resisted the sub-aërial disintegration more effectively than has the limestone; therefore the denudation of the valleys has not proceeded beyond or far into the trap.

Description of rock groups and sections.—I was able to distinguish the following groups of rocks between the Indus and the Helmand in descending order:—

RECENT	...	Alluvial and aërial.
POST-PLIOCENE	...	Conglomerates, clays, etc.
PLIOCENE	...	1. Manchhars (Siwaliks).
MIOCENE	...	2. Gáj beds.
EOCENE	...	3. Nummulitic limestone 4. Ranikot group 5. Alveolina limestone = 1. Nummulitic limestone. 2. Sandstone, shales, etc.
CRETACEOUS	...	6. Dekkan trap, etc. 7. Upper cretaceous limestones, shales, etc. 8. Hippuritic limestone and contemporaneous traps.
ERUPTIVE ROCKS.		1. Trap. 2. Felsiteporphyry. 3. Hornblendic granite.

Recent formations: Alluvial and aërial deposits.

Denudation by rivers.

The present great rivers of Afghanistan and of the Brahuik country have all formed deposits of more or less structural importance along their courses, consisting of gravels, coarse shingle, and loose material derived from the surrounding

hills. In the Afghan area, to which most of the harder (limestone and igneous) rocks are confined, sub-aërial denudation and wasting seem to be inconsiderable, and as a consequence the last deposits formed by the existent rivers form but a thin plastering over the older rocks and the post-pliocene deposits beneath; the material carried out of the rocky valleys of the Argandab, the Tarnak, the Helmand, etc., is gradually disintegrated and deposited in the great open plains of the lower courses of these rivers. The conditions are different in the Brahuik and Marri country, where the rivers traverse in turn the cretaceous and tertiary series, and especially the latter affords in the sandstones and shales ample material to be disintegrated and carried away to the plain of the Indus as gravels, and finally as clays and sands which now cover the Sibi-Dadar plain in great thickness.

Aërial formation.

But of especial interest seem to me the vast deposits of aërial origin, now covering extensive tracts of country, not only in the great deserts of Kegistan, of Seistan, etc., but which also encroach rapidly on the more fertile plains of Southern Afghanistan—the valleys of the Helmand, Argandab, the lower Khakrez, and the great tracts lying between Kandahar and Quetta. These deposits may be well studied along the banks of the lower Dori and lower Argandab. Time and opportunity were too limited to admit of my devoting much attention to these interesting deposits. Suffice it to say that the great desert tracts lying south and south-west of Kandahar are formed of huge accumulations of blown sand and blown material of all kinds, amongst which a fine densely red clay is conspicuous. This latter is derived, I believe, solely from the gypseous red clays of the Gáj group, which gradually, under the influence of sunheat and storms, waste away as fine silt or powder to be re-deposited further on. Such deposits may be studied all along the course and south of the Dori and Argandab rivers, where a succession of waves is made up of this material. The wide course of these rivers and their ever-acting force has to a certain extent arrested the progress of these huge moving aërial masses, but already the finer material carried by the currents of air reach the opposite banks and descend in sandstorms on the open tracts

between the Helmand and Quetta, resting in shifting patches and, in sheltered places, in thick deposits on the post-pliocene gravels. The isolated hill ranges south of Kandahar show this feature well. The loose material, constantly changing its position, is seen to surround and creep up into the hollows, creeks, and fissures of the jagged cliffs of limestone and trap. Every season material is thus added, and the time must come when the whole valley of Kandahar will be covered by this deposit and merged into the endless desert tracts lying at present south of it. Slow though this change may be, and though it may require many centuries, nevertheless it is certain that it must come about.

As we travel further northward, the aërial deposits become thinner and thinner as a covering of the underlying post-pliocene rocks, and form mere irregular and shifting patches. Whilst the prevailing scorching sandstorms deposit sand and loose material at one place, they also mechanically remove the lighter and disintegrated substance from off the surfaces of the rocks and from off the ground in other places. Nearly all the great valleys of Southern Afghanistan are covered with post-pliocene deposits in great thickness; amongst them is conspicuous a deposit of gravels and irregular fragments of rock from the surrounding hills, more or less firmly cemented together by a calcareous and argillaceous matrix, forming a kind of breccia. After disintegration has taken place on the surface of this deposit, the prevailing sand-charged storms remove such decomposed material, leaving the larger particles, namely, the pebbles and angular rock fragments, behind, producing wide spreads of these stone-strewn plains, characteristic of this part of Asia and commonly termed *dasht* by the natives.

That these steady currents of air are ever active as eroding agents is well proved by all the bare hill sides, but by none better than the exposed and isolated hippuritic limestone cliffs south of Kandahar; the currents of air charged with sand scoop out into hollows and deep caverns the sides of the hills exposed to the south and south-west, leaving always a fresh but rugged surface on the rocks. This feature has reminded me of an area nearly 5,000 miles distant from Kandahar, namely, the Cape; the fierce south-westerly storms which prevail there have eroded the surface and top of the Table-mountain of the Cape into

most curious shapes and hollows, all of which are directed to the south-west. Here, however, the tool used for scooping out these hollows is not brought from a distance, but originated on the spot and derived from the easily disintegrating sandstone of the Table-mountain plateau.

I cannot close this section without referring to the theories put forth lately to explain the great accumulation of loose material in the deserts of Central Asia. Freiherr von Richthofen, in his great work "China," has first established the fact of the connection between these deposits and the sandstorms, common over nearly the whole of Central Asia, but has at the same time compared these wind-formed accumulations with the loess of Europe. This Dr. Jentzsch[1] is not disposed to accept, holding, as he does, the opinion that the loess of Europe, at least the greater part of it, admits of the explanation put forth by Freiherr von Petrino,[2] and other Austrian geologists. Dr. E. Tietze, who has travelled over a considerable part of Persia, and who has studied many of the great wastes of sand in that country, shares Freiherr von Richthofen's views, at least as regards the formation of the Central Asian deserts.[3]

This is also the view held by Mr. W. T. Blanford,[4] and certainly this theory explains easily the existence of these huge deposits, more or less without stratification of any kind, of loose material found over such a large area of Southern Afghanistan. But at the same time I must confess that these deposits, as far as I know them, bear no, or very little, resemblance to the loess deposits, as I know them, of Austria.

Post-pliocene deposits.

Sections in *karezes.*

One of the characteristic features of an Afghan landscape and also of most Central Asian districts are the artificial and underground watercourses called *karez*. The natives of Afghanistan possess great skill in tracing the presence of subterranean flows of water, follow them and dig underground channels for them, communicating with the surface by means of shafts at short intervals.

[1] Verh. K. K. Geol. Reichsanstalt, 1877, p. 251.
[2] Verh. K. K. Geol. Reichsanst., 1870, p. 79.
[3] Jahrb. K. K. Geol. Reichsanst., 1877, p. 341.
Jahrb. K. K. Geol. Reichsanst., 1878, p. 581.
Verh. K. K. Geol. Reichsanst. 1878, p. 113.
[4] Progs. R. Geog. Soc., 1881, p. 79.

FIG.1. GIRISHK.

Such water-courses extend often many miles in the waste plains of Southern Afghanistan, and only by their help are we enabled to study the nature of the rock beneath the recent alluvial and aërial deposits. The great valleys of the Pishin, of Kandahar, of the Argandab, and of the Helmand, not less than the smaller ones of the Brahuik hills (for instance the Kirtha valley), are covered on the surface by recent alluvial soil; but immediately below that, and often protruding through it, may be seen a hard conglomeratic deposit of great thickness, which the karez-makers have to penetrate when in search for water. This conglomerate consists here and there of rounded pebbles, but mostly of angular fragments of the surrounding rocks, cemented together by a calcareous matrix. Nowhere is this formation so well seen as on the banks of the Helmand river.

I visited this river near Giriskh, and found that the left bank of the river for many miles consisted of thick beds of this conglomerate forming steep scarps, facing the river. It may be seen there how superficial is the deposit of recent sands and gravels resting on it. The right banks are also formed of these brecciated or conglomeratic beds, but the scarp which is formed by them is not so apparent, and altogether there is a wider belt of alluvial deposits found there than on the left bank.

Conglomerate of the great valleys.

The same conglomerate may be found in all the open valleys of Southern Afghanistan, and there can be no doubt that in it we see represented a vast deposit formed by the action of water; it may be looked upon as the product of systems of rivers, the former existence of which is proved by the wide valleys, the rivers of which are now dry. Beneath these gravels and conglomerates occur sands and clays, on which the water is usually met with in sinking karezes.

Sections near Nari gorge.

The best section where the relative position of these gravels to the lower rocks may be studied is along the eastern margin of the Brahuik and Marri hills. On plate I, profile 3 and 4, I have given views of the contact of the gravels (*a*) and the Manchhar rocks (*b*), the latter dipping at about 35° to 40° east. The gravels and conglomerates with subordinate clay partings rest quite unconformably on an eroded surface of the Manchhars, from which the recent beds slope at a low angle to the east, gradually assuming the horizontal position to form the great Indus (Sibi-Dadar) plain. Dr. A. Fleming[1] has described this deposit of conglomerates very well, though from a locality further north-east, namely, from the Dera Ghazi Khan frontier. There also it rests unconformably on the sandstone of Siwalik nature (Manchhars).

Laterites.

In connection with these post-pliocene deposits of Southern Afghanistan, I must mention considerable deposits of laterite, which creep up into the depressions and fissures of the rocks composing the hills of that country. They

[1] Quart. Journ. Geol. Soc., IX, p. 346.

are seen to perfection skirting and plastering over the base of the hippuritic limestone hills of Kandahar and the Shah-Makhsud range. I believe this variety of laterite to be identical with the Nyirok, as Szabo[1] calls the post-pliocene laterite of the Karpathians. His explanation—that it is simply the result of the decomposition of various eruptive rocks—would agree with the fact that the laterite of Southern Afghanistan occurs also in the immediate neighbourhood of the upper cretaceous traps.

PLIOCENE.

Manchhars.—The rocks comprising this group are best seen in a magnificent section exposed in the Nari gorge near Sibi along the line proposed for the Sibi-Kandahar railway (prof. 2 Pl. I). The river Nari has cut through a great anticlinal fold of Manchhar rocks, and has done this at an exactly right angle to the strike of the beds, so that a perfect natural section is obtained. Owing to the prolonged hostilities with the Marri tribe, which prevailed during my stay at Sibi, I was not able to penetrate further than the cavalry outposts, which were sent daily from Nari gorge up the valley.

I have therefore not been able to observe the contact of the Manchhars with the underlying rocks in the section in question, but such an opportunity was afforded me in the Bolan pass which I shall describe presently. Near Nari gorge the series consisted of clays and gravels with conglomerates near the upper part; towards the base the series gradually assumed the character of a regular alternation of sandstones and sandy clays. The sandstones are fine grained, of a brownish-grey pepper-and-salt appearance, with occasional pebbles enclosed. The clays are of the same drab, and here and there salmon, colour, and contain a good deal of sandy material, assuming in places a hard sandstone-like appearance. Towards the base the clay predominates and changes slightly in tint, reddish-brown prevailing.

Very thin veins of gypsum are common throughout; the crystals of that mineral filling up fine cracks and fissures in the rock.

[1] Verh. K. K. Geol. Reichsanst., 1867, p. 244.
Verh. K. K. Geol. Reichsanst., 1877, p. 158.

I have endeavoured to show the geological features of the Nari gorge section in pl. I, figs. 2, 3, and 4. Fig. 2 is a camera sketch taken from a point about 1½ miles up the valley and on the left bank of the river, thus commanding a good view in the strike of the beds opposite. On the extreme left (south) of the profile is seen the contact of the post-pliocene gravels and clays of the Sibi-Dadar plain. The latter formation is seen to rest quite unconformably on the sandstone and conglomerate beds of the Manchhars. To illustrate this clearly I have given the figs. 3 and 4, which shows the same spot from a nearer point of view. In these figures, *a* represents the post-pliocene gravels, with partings of sandy clay forming steep cliffs along the river bank and gently sloping from the denuded Manchhars, *b*, down to the Indus plain, where the beds are quite horizontal. Near that spot the Manchhars are mostly composed of a conglomerate, made up of pebbles of eocene rocks; towards the lower beds the conglomerates gradually disappear and sandstones take their place, which are gradually supplanted by clays as we descend in the section.

Northwards (right in the profile) of fig. 2, the anticlinal fold of the Manchhars is clearly visible; about 1 mile further up in the gorge the beds are still seen to dip northwards, but beyond that point I was not permitted to travel.

The point (*right* in the profile) near the bend of the Nari river, beyond which the Manchhar beds dip northwards, is the centre of the section, and supposing that near it the lowest beds of the Manchhar group are exposed, it would give, with a length of two miles and a dip of from 40° to 45°, a total thickness for the Manchhars of from 6,000 to 7,000 feet. But I have no reason to suppose that this point marks the lowest bed of the Manchhar group, which may exceed considerably in thickness, 7,000 feet. I traversed a similar and very instructive section of this group near the entrance to the Bolan valley, between Pir Chowki and half-way to Kundilani stations. East of Dadar the variegated and red and white clays of the Gáj group are seen to dip westward beneath the pinkish-

Manchhars of the Bolan.

drab clays of the Manchhars. The contact is not quite clear because obscured by superincumbent post-pliocene beds; but since the dip is identical, I have no reason to think that the Manchhars are unconformable, though there may be, and probably is, a considerable overlap of the latter over the former, as the section shows further on. Near Pir Chowki the Manchhars form a precipitous cliff facing the south, shown in fig. 1 of pl. II, here and there broken by the denudation of small rivulets and springs. This cliff extends in a north-east to south-west direction for about 30 miles. Southwards of this line the Manchhar hills range due north and south, further on joining the west Sind districts surveyed by Mr. W. T. Blanford. Northwards of the Bolan ridges of Manchhars, the latter strike away towards the east and include in that direction the Nari gorge beds already described.

The cliff presents a most striking feature in the landscape of that part of our frontier; bare brownish-drab hills of sandstone, with a steady north-west to west dip, range themselves in front and rising abruptly from the sandy plain of Dadar. Beyond can be seen the white, in the distance snow-like, cliffs of the nummulitic limestone (*a*). The Manchhars form entirely the outer parallel ridges of the Bolan-Marri hills, and apparently form one or more great folds; in some of the sections, as for instance in the one near Nari gorge (figs. 2, 3, and 4, pl. 1), we see nearly the entire series of rocks composing this group, with the upper beds overlapped by the post-pliocene gravels of the Indus valley; whereas along a great portion of the outer cliffs, the beds at the axis of flexure have been denuded away, leaving a bold and precipitous cliff towards the plain, as is the case near Pir Chowki, and north-eastwards towards the Mushkaf river.

The lower rocks at Pir Chowki are the same as at Nari gorge, composed of clays and sands of a greyish-drab colour, with a few beds of pepper-and-salt coloured sandstone. This sandstone becomes more prominent towards the upper horizon, and until we reach the last few hundred feet of the group, which are mostly composed of gravels and conglomerates.

At Pir Chowki the outer half of the arch having been denuded, the

beds appear to dip inwards, and on ascending the gorge towards Kundilan the strata are seen to undulate gently and form one or two smaller folds, until the whole group is seen to rest unconformably against a steep escarpment of the nummulitic group, about half-way between Kundilani and Pir Ckowki.

Fig 2. Section between South Kirtha (Bolan) and the Indus plain near Dadar. 1. Post-pliocene deposits. 2. Gaj beds. 3. Manchhars. 4. Ranikot. 5. Nummulitic limestone.

The contact is quite clear; a high and precipitous cliff, fig. 2, of yellowish or dirty white limestone of the nummulitic group (5), with underlying Ranikot shales and clays (4) is partly overlaid by (3) Manchhar sandstones and conglomerates, dipping slightly from the older cliff. The beds are too much folded and disturbed near Pir Chowki to permit of computing the thickness; but since near the contact with the older rocks no trace of the Gáj group appears, it seems probable that the Manchhars overlap this group.

The disturbed condition of the country, and my consequent short stay in that part of the hills, account for my having no fossils to show from this group; but no doubt a steady and systematic search will be rewarded with success.

Miocene series.

3. Gáj group.—Near the boundary between Biluchistan and Afghanistan I first noticed rocks, which I could at once identify with the Gáj group as described by Mr. Blanford in Sind.

Also in the Dadar-Sibi plain, beds of clay of bright red, bluish-white and variegated colours (2 in fig. 2) crop up from below the post-pliocene gravels of the plain and form low undulating hills between Mittri and Dadar, visible from afar on account of the bright-coloured

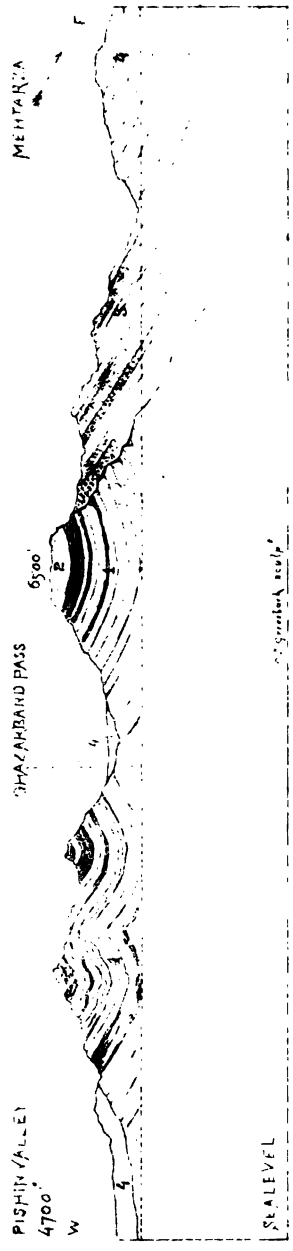


Fig. 3. Section between the Pishin valley and Mehtarzai
1. Eocene shales and sandstones. 2. Nummulitic limestone. 3. Sandstones and conglomerates (lower Gáj). 4. Gáj beds.

scarps and denuded surfaces. These clays dip towards the north-west at an angle of from 40° to 45°, and apparently below the Manchhars of Pir Chowki. The peculiar type of the rocks and the existence of numerous masses and irregular beds of gypsum (Pushtu: *gáj*) at once suggested the identification with Blanford's Gáj group. But by far the most important locality of this group as occurring within my area is along the eastern slope of the hills over which the Ghaziaband pass leads into the Pishin valley.

Ascending the pass from the Quetta side, the eocene group (nummulitic limestone) is seen to form a high (5,500 feet above sea) escarpment facing the east (1 and 2, fig. 3), against which coarse, brown, friable sandstones, with intercalated beds of conglomerates, are seen to rest as shown in fig. 3. The angle of dip varies from 20° to about 40° east, but towards Mehtarzai on the Quetta road the beds are a good deal crushed, and some of them nearly vertical. The complex of sandstones has a considerable thickness, and extends from the top to nearly the foot of the pass; they are followed by masses of bedded reddish-brown clays with subordinate sandstone beds, gradually merging into densely red and white clays and marls

with gypsum beds. The uppermost beds fringing the whole of this range (the Dinar range) are composed of brilliantly white clays with lenticular masses, veins, and beds of gypsum, extensively made use of by the native builders. I was not long enough in the neighhourhood to collect fossils, but the appearance and position of the rocks is so characteristic that there can be no doubt that it is the Gáj group of Sind. This group extends over a large area on the boundaries of Biluchistan and Afghanistan. The whole of the Dinar range is fringed on all sides by it, and the low hills on the right bank of the Kakar Lora river are composed of it. How far these beds extend into the Northern Pishin valley I cannot say. But as far as I could see, they encircle the Dinar range, forming a fringe along the east and west slope of it, joined together by the low hill area of the Kakar Lora between Haidarzai and Gwál, and fill up all the lower valleys and bays formed by the eocene group (see 4, on west in fig. 3).

The Haidarzai-Gwál area is shown in profile 1, pl. II; the red and white gypsum clays of the Gáj group form a large and barren low area, along and (further on) through which the Kakar Lora wends its way. Towards the east and south-east this group presents rather a steep escarpment (2 in profile 1, pl. II), furrowed and denuded by each rainy season. The relation to the underlying nummulitic limestone (1) is not quite clear near Manzakai, because the valley (about three to four miles wide) is covered up by extensive alluvial deposits, but since the dip of both groups is there the same, nothing would indicate such an unconformity as that exposed in the Ghaziaband section. On crossing the latter section into the Pishin valley, a narrow strip of Gáj beds is disclosed along the west slope of the nummulitic rocks forming the pass, which beds are further on covered up with the alluvial deposits of the Pishin. But south-westwards of the range, so far as the eye can reach, a low hilly ground, more or less quite barren, extends and closes the Pishin towards the south. This low ground is composed, as far as I was able to penetrate on my march to Kandahar, of the bright-coloured gypsum clays of the Gáj group, and this area I

found is connected with the narrow strip on the west slope of the Ghaziaband aforementioned.

Probably the whole of the ground of the Pishin and the valleys of the Dora and Tarnak rivers are composed of this group, though now covered up by the hard conglomerates and gravels of the post-pliocene beds. In most of the valleys the natives by digging deep enough reach the deposits of *gáj* (gypsum) which they use in building their forts and houses.

I believe also that the enormous desert of Registan south-west of the Dori and Argandab is made up of disintegrated material of Gáj rocks. I have not crossed any part of this desert, only touched it at several places. Near those localities (Abdul Rahman for instance) the rocks (clays and sands) are of precisely Gáj character, and the country resembles exactly the area between the Pishin valley and Kasim Killa in the Gwál valley.

Eocene group.

4. The eocene rocks.—Rocks belonging to the eocene formation occupy by far the largest area in Biluchistan, and extend over a considerable portion of Southern Afghanistan. Of the former country, as far as it came under my observation, the chief ranges of the Brahuik and Marri hills are composed of eocene rocks; whereas the Bolan pass, that is the watershed between the Bolan river and the confluents of the Lora, is made up of upper cretaceous limestones. In Southern Afghanistan the principal part of the Kojak-Amran range and probably the Toba plateau are eocene.

On the map I have coloured the whole eocene area with one colour only, as it would have been impossible to define the boundaries between the different groups of eocene rocks with anything approaching accuracy in so short a time.

Travelling over the ground between Kandahar and the Bolan, it becomes at once apparent that the eocene group is represented by rocks of different facies in two distinct areas, in which respect I was at once reminded of the eocene rocks of Eastern Austria and Hungary.

The Biluchistan or eastern area comprises all the eocene rocks east of the Ghaziaband (Dinar) range, and therefore the limit of the region forms also the political boundary between Afghanistan and

Biluchistan; all the eocene rocks forming the Ghaziaband range and lying west of it belong to the flysch or Afghan area.

The eastern region consists in descending order of—

1. Nummulitic limestone.
2. Ranikot group.
3. Alveolina limestone.

The rocks, as it will be seen, forming this group in Biluchistan are chiefly limestones and clays; whereas *the Afganistan area* is constituted in descending order of—

1. Nummulitic limestone.
2. Shales and sandstones (of flysch character).

1st Eocene area (limestone facies) : Biluchistan.

Bolan Pass and Quetta valley.— For convenience of description I begin with the lowest beds (3) of the area, namely, the Alveolina limestone. Near Sir-i-Bolan and other localities in the Brahuik hills I found immediately above the upper cretaceous trappoid beds (olive shales of Blanford) a complex of light-coloured sandstones with indistinct traces of *Ostrea*, and some hard shales with subordinate beds of limestones also containing *Ostrea*. There is nothing to show to which group these doubtful beds, which are of considerable thickness, should be placed; they form a complete passage from the olive shales with associated trap to some hard light grey limestone in thin beds, filled with a small species of Alveolina. These rocks are well developed in the hills west of Quetta, dividing this valley from that of the Kakar Lora; a fine section through the entire series is obtained west of Kari in the Quetta valley.

But by far the best exposures are along the road from Dozan to Sir-i-Bolan in the Bolan pass, where this passage group from the cretaceous to the nummulitic series forms almost vertical cliffs along which the dark trap band and dark liver-coloured shales of the upper cretaceous show plainly as a distinguishing land mark. The Sir-i-Bolan series has a slight but steady easterly dip, and falls in below the Ranikot group near Much.

The Ranikot group. (2).—This group rests immediately on the Alveolina limestone. I found it near Much in the Bolan well exposed in the river; this locality has lately excited considerable interest on account of the seams of coal found within its area.

Though the structural features of the locality are very complicated on account of the folding and crushing the whole series has undergone, I was able to unravel the following section along the left bank of the Much river, near the commissariat station of that name; in descending order the beds are—

		Ft.	In.
1.	Yellowish-brown clay, with grey nodules of the same.		
2.	Flaky lignite with clay, thickness 2″ to 3″.		
3.	Light grey clay	20	0
4.	Lignite with clay partings	0	3
5.	Calcareous clay	0	1
6.	Friable coal-seam	0	3
7.	Calcareous clay	0	1
8.	Coal	0	3
9.	Reddish clay	0	2½
10.	Coal	0	2
11.	Clay	0	7
12.	Bituminous shaly clay	0	6
13.	Sandy ferruginous clay	0	6
14.	Lignite	0	4
15.	Calcareous band	0	1
16.	Bituminous purple clay	0	4
17.	Calcareous clay	0	1
18.	Lignite	0	5
19.	Yellow clay with *Turritella*, sp. *Pleurotomaria*, sp. etc. ...	0	4
20.	Thick bed of grey clay with thin partings of sandy shales.		
21.	Ferruginous sandstone in beds of varying thickness, shaly towards base.	...	...
22.	Clays with sandstone partings and thin seams of lignite, base hidden.	...	...
23.	Densely red ferruginous shales much contorted, with anthracite like fragments of coal inclosed, as well as masses of spongy iron ore.	...	...

On the right bank of the same nulla a similar section is exposed rather higher up the river and much contorted; but the following succession may be made out in descending order.

	Overlying rocks: Nummulitic limestone.	Ft.	In.
1.	Rocks immediately below hidden by debris, but about 100 feet below is—		
2.	Brownish hard sandstone in even beds.		
3.	The rocks below again hidden for a considerable distance.		
4.	Bituminous clay and lignite seams	6	0
5.	Clay with limestone partings	7	0
6.	Clay with ½" coal partings	2	0
7.	Clay	2	4
8.	Coal	0	2
9.	Bituminous clay and limestone partings	1	0
10.	Clay	3	0
11.	Bituminous clay and limestone partings	1	6
12.	Coal	0	2
13.	Bituminous clay	0	6
14.	Calcareous bed	0	3
15.	Lignite	0	1
16.	Calcareous bed	0	4
17.	Coal	0	5
18.	Clay with bituminous partings	4	6
19.	Very friable coal with shale partings	1	0
20.	Clay with thin lignite seams	7	0
21.	Purplish mass of clay	0	0
22.	Thick mass of sandstone with a flaky thin seam of lignite (½") ...	0	0
23.	Clay with seam of lignite (1")	2	0
24.	Lignite	...	3"
25.	Clay	7'	...

26.	Coal and clay partings; the coal is very friable and the thickness of the layers does not average more than 2" to 3" ...	2′	6″
27.	Bituminous clay	...	5″
28.	Clay	1′	2″
29.	Bituminous clay	1′	...
30.	Sandy calcareous bed	...	6″
31.	Greyish sandy clay	2′	...
32.	Sandy fossiliferous limestone with *Cyprina subathooensis* D'Arch, *Cypricardia* sp.	4′	...
33.	Thick mass of clay with partings of sandstone and bituminous streaks.		
34.	Lignite	...	5″
35.	Clay with hard layers	3′	...
36.	Same as (32)	...	3″
37.	Lignite with streaks of shining coal	...	8″
38.	Bituminous shaly clay and partings of coal	2′	6″
39.	Sandstone	...	2″
40.	Lignite with thin shale partings	1′	...
41.	Sandstone	...	1½″
42.	Lignite	...	2½″
43.	Yellow clay and coal	...	4″
44.	Coal	...	2″
45.	Clay	...	1″
46.	Black shining coal	...	2″
47.	Bituminous shale	...	1″
48.	Shining black and very friable coal	...	3″
49.	Brown flaky coal	...	5″
50.	Calcareous clay	...	6″
51.	Flaky coal	...	3″
52.	Calcareous clay.		

53.	Thick mass of grey clay.	
54.	Yellow argillaceous band with grey clays.	
55.	Grey sandstone alternating with yellow concretionary clay.	
56.	Thick mass of pepper-and-salt-coloured sandstone, very hard, in uneven beds, with concretionary masses of yellow cherty rock.	
57.	About 100′ covered with debris, etc., with here and there clay beds visible beneath it.	
	Underlying rock: Alveolina limestone.	

It was exceedingly difficult to unravel the above section, the whole complex of beds being contorted into many and close folds, no doubt owing to the peculiar soft and yielding nature of the Ranikot group, which may have been pushed over the harder underlying limestones by the great pressure which must have acted from the south-east towards north-west, without affecting the underlying rocks so much as the clays and shales of the Ranikot group. Instances of this feature I have several times observed in other localities, notably in the Himalayas.

Fig. 4.—Section of Ranikot beds in the Much nullah (Bolan).
1.—Ranikot beds. 2.—Nummulitic limestone. 3.—Post-pliocene gravels.

In the annexed section, which is the one above described, the folding of the Ranikot beds is clearly shown; the whole is covered up by the horizontal beds of gravel and sands with subordinate clay layers of the post-pliocene deposits.

The Ranikot beds are of marine origin, as the fossils abundantly prove; the deposits were evidently precipitated on or near a shallow part of the eocene sea, favourable for the growth of seaweeds, which are now preserved as the thin seams of flaky coal. This shoal must have ex-

tended over a considerable area; Mr. Blanford has first described the group from Western Sind,[1] and there can be little doubt that the coal-bearing strata which Mr. Ball has described from the Chamarlang valley west of Dera Ghazi Khan[2] also belong to this group.

The coal-bearing deposits of Sharigh, on the Hurnai road, are evidently a continuation of the Ranikot beds of Much and Abigoom in the Bolan, and thus this locality forms a connecting link in the long strip of deposits which skirts the old eocene seacoast. That the coal-bearing beds of the Ranikot group occupy a narrow strip only is plainly shown by the fact that both east and west of the belt between Much and Abigoom, a distance of about 10 miles, the clays and argillaceous limestones which crop up from below the nummulitic limestone do not yield coal beds. This equivalent of the Ranikot, devoid of coal seams, is well seen between Kirtha and Kundilani in the Bolan (see fig. 2), where the soft clays and shales are seen to underlie the nummulitic limestone in great thickness.

The group is greatly disturbed and folded into countless waves, and also locally (as at Much) shattered and jointed, so that it is almost impossible to obtain a continuous section.

It scarcely needs explanation that beds of coal of about 1 foot thickness are not likely to prove of much use economically. Where the seams are well exposed and the coal can easily be scraped out of the clay, it may be of local use for fuel; but such supply from surface workings could not last long; besides the coal is so friable and contains so much sulphur and iron pyrites that it would not be advisable to use it for smiths' purposes, as it would render all iron very brittle.

In profile 2 of Plate II, illustrating the structural features of the Kandhar range north-east of Abigoom in the Bolan, the relative position of the Ranikot group to the overlying nummulitic limestone is clearly seen. The latter, a massive white limestone full of eocene fossils, overlaps the coal-bearing Ranikot group conformably; the whole series forms a huge dome over the Kirtha valley, of which the Abigoom

[1] Mem., Geol. Survey of India, Vol. XVII.
[2] Rec., Vol. VII.

corner forms the northern part. The centre of this dome has fallen in, leaving the margins with steep scarps facing inwards. The present centre of the valley near Kirtha and other places shows still the remains of the upper part of the arch (see Plate III).

Further southward the Ranikot group becomes somewhat changed in character; the coal seams disappear; but there are still (figs. 2 and 4) light-coloured clays with a few calcareous beds and several thick beds of sandstone, the whole resembling in general character and relative position the Much series of the Ranikot group, but minus the coal beds. I found similar rocks, chiefly yellow clays, but containing nummulites, east of North Kirtha in the Bolan. Along the whole of the base of the hills, which run about north to south, they occupy the position below the nummulitic limestone, which is shown in Plate III.

Nummulitic limestone (*1, page 22*).—By far the most extensively represented rocks in the Bolan pass are limestones of varying character, full of nummulites, echinoderms, and bivalves; they invariably overlie the Ranikot beds conformably. The best section I obtained was in the Bolan near North Kirtha. The section profile, pl. III., which is taken from a point nearly 3,000 feet above the sea, shows the whole thickness of the nummulitic limestone. The beds at the base of the cliff east of Kirtha are clays, which probably still belong to the Ranikot group as explained before. But above that is an uninterrupted series of limestone beds. The rock is of a very dense character, of a greyish-yellow colour, and all of them, including the upper clay beds at the base, contain nummulites, in fact in some places the rock seems quite made up of them, along with many echinoderm remains and a few bivalves. The nummulitics formed here a huge arch or rather dome, as already explained, page 27; the beds dipping away from the centre of the valley all round. Near Much the dip is north-east, and grand cliffs are exposed in the high range of hills north of the halting ground.

Owing to the disturbed state of the country the upper beds of the eocene group were only accessible to me at a few spots, but the lower beds traversed I found to be very hard, white, sugar-like, almost crystalline

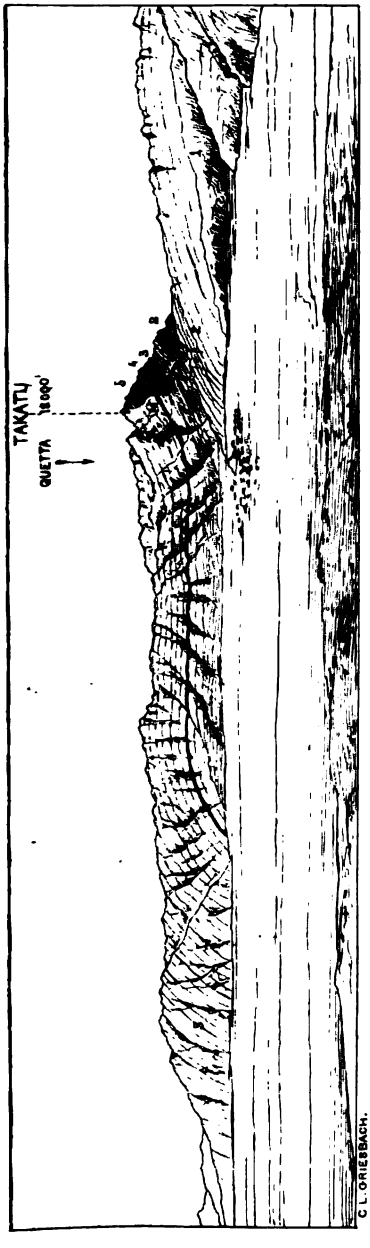


Fig. 5. Profile of the Takatu near Quetta.
1. Hippuritic limestone. 2. Variegated flags. 3. Ostrea limestone. 4. Trap band. 5. Eocene group.

limestone full of nummulites, small bivalves and echinoderms; this limestone rests quite conformably on the Ranikot beds, and the boundary with that group is distinct and well defined. The only other locality where I have observed this facies of the nummulitic limestone is north and south-west of Quetta. The grandest exposure of it is seen along the top and north-west slope of the hill group of which the Takatu is the highest point (about 11,000 feet).

The hill mass of the Takatu was, of course, quite inaccessible to me, but I have skirted along the base of the range exposing the section shown in fig. 5; and afterwards I had an opportunity of crossing the Murghi pass, leading from the Quetta valley into that of the Kakar Lora near Kasim Killa and to Manzakai in the Gwál valley. East of Manzakai in the Kakar Lora valley the nummulitic rocks are well exposed on the north-west slope of the Takatu. Small rivulets have cut through the limestone beds, showing the lower ones as being a fine-grained, hard, very light grey or white limestone; whereas the upper beds are dense-grained, reddish or reddish-brown limestone, both full of nummulites (profile 1, pl. II). Similar rocks prevail in the continuation

of the Takatu range west and south-west of Quetta, the lower beds of which are still shown in the profile 1, pl. IV. The range is divided west and north-west of Quetta by the denudation of the Lora river, but, as might be expected, the character of the eocene (nummulitic) rocks is precisely the same as that seen north-west of the Takatu hill.

In connection with the nummulitic limestone I met with a singular rock, largely developed in the Bolan pass. South of Kirtha, between that halting place and Kundilani, the nummulitic limestone changes gradually upwards into a yellow argillaceous limestone, devoid of fossils, which is followed soon by huge masses of the same rock, quite devoid of bedding, but of concretionary appearance, which, when passing it at night on my way to Kandahar in the early spring of 1880, I mistook at first for conglomerate. The argillaceous limestone is formed of moderate sized concretions, all cemented together by a matrix of the same character; subsequent aërial denudation has partly removed this cementing matrix and left interstices and hollows between the individual concretions, thus giving it the appearance of a conglomerate. This peculiar rock forms high cliffs and narrow gorges in the Bolan pass above Kundilani. Whether it may be looked upon as a representative of the Nari group of Mr. Blanford, I cannot say, not having found any fossils. But the concretionary rock of the Bolan rests conformably on the lower nummulitic limestone, and in fact passes gradually from this rock and may perhaps merely do so locally; at least the section which I saw between Kundilani and Pir Chowki (fig. 2, page 18) gave me this impression: Manchhars rest there unconformably against a high cliff of the concretionary nummulitics, below which occur clays and shales which I take to be representatives of the Ranikot group.

2nd Eocene area (flysch facies): Afghanistan.

a. Ghaziaband pass and range.—Close to the boundary line between Biluchistan and Afghanistan I came upon a series of rocks quite different in lithological character from those described from the Bolan Pass.

Were it not for an inconsiderable thickness of limestones containing nummulites which occurs within this area, I should be entirely in the

dark concerning these rocks; but with the help of this fossiliferous limestone the following section can be made out in descending order:—

3. Nummulitic limestone.
2. Sandstone group.
1. Shaly group.

The lowest group of beds composing this area is the—

Shaly Group (*1*).—The succession of beds of this group can best be seen along the road which traverses the Ghaziaband pass, and of which I have already given a profile (fig. 3, page 19).

Near the western entrance to the pass I saw a great thickness of drab and grey coloured, often banded, clay shales, here and there of extremely fine-grained texture with a silky feeling to the touch and splitting into leaf-like fragments. They are alternating with sandy shales and thin-bedded sandstone. In the sandstone I found traces of *Ostrea*. Here and there the bright greyish green-coloured silky shales have distinct fucoid markings on the partings; and altogether the whole complex reminded me forcibly of the shales of the eocene flysch of the northern outer Alps. The likeness is still enhanced by the next group.

The Sandstone Group (*2*) passes insensibly from the lower beds; the silky shales still exist, but only as thin partings between sandy shales and sandstones in thicker beds, and the latter increase in general importance until nearly the whole group consists of it. It is a brownish grey, rather fine-grained sandstone in which I have found no fossils. This is a genuine likeness of the Vienna-sandstone, the upper portion of which is eocene.

In the Ghaziaband pass the sandstone forms the uppermost portion of a succession of parallel synclinal hills to the west of the pass itself, which is flanked by the highest part of the range, and which shows this succession of beds very clearly. Luckily for the elucidation of the age of these beds, the sandstone group is overlaid in the Ghaziaband (fig. 3, page 19) by the nummulitic limestone.

The Nummulitic limestone (*3*) rests conformably on the sandstone-group. Lithologically it differs slightly from the nummulitic limestones

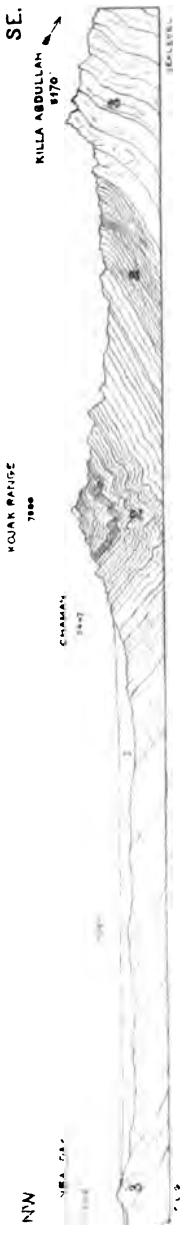


Fig. 6.—Section between Spinbaldak and Killa Abdullah.
1.—Post-pliocene deposits. 2.—Eocene group. 3.—Cretaceous limestone.

of the Bolan. It is generally a dark blue or grey concretionary limestone, in places reddish-brown even, containing numerous large species of nummulites.

As shown in the fig. 3, page 19, the beds of this second eocene region are much contorted; the yielding nature of the material, mostly soft shales, has given rise to numerous small faults and a great deal of jointing, so that I could not arrive at a correct guess of its thickness during the short time at my disposal.

As will be seen further on, this series rests on upper cretaceous limestones at another locality, so that this fact, in conjunction with the presence of the nummulitic limestone which overlays it, proves nearly conclusively that the complex of shales, sandstones, and argillaceous limestones belongs to the lower eocene formation.

b. Amran Range.—I crossed this range only over the Kojak pass, but skirted it along its east slope as far as Gulistan Karez. Fortunately I have a second section across it put at my disposal by Lieutenant W. W. Robinson, R.E., who crossed the range over the Gwaja pass.

The Kojak range, as shown in fig. 6, is a synclinal, formed chiefly of the rocks of the first and second groups described from the Ghaziaband pass. In addition to the soft and silky shales with intercalated clays and sandstones, I found several limestone beds of considerable thickness; and the whole have a strike more or less parallel to the general direction of the mountain range.

It would be almost impossible to unravel a succession of the individual beds; the whole has been subjected to such lateral pressure that the dip varies every few dozen yards; besides which, faults and joints run through the series, mostly parallel to the line of strike. Between Spinbaldak (west) and the Kojak pass stretches an enormous deposit of post-pliocene gravels and sands, which of course obscures the section. But there can be no doubt that the interpretation as put in fig. 6 is the right one; the hippuritic limestone of Spinbaldak dips to east and south-east, as if below the Kojak shales. The latter are seen to rest, apparently conformably, on a limestone (3) of Killa Abdullah in the Pishin, which I identify with the hippuritic limestone of Spinbaldak on lithological grounds. The whole seems to me to form a great synclinal trough in which are now inclosed the numerous plications of the eocene Kojak shales.

When proceeding to Kandahar in the spring of 1880, in company with troops, I had to perform most of the marches by night or at least during the dark hours of the morning, so that I only got glimpses of the rocks at intervals. I then compared the Kojak shales with the Naini Tal rocks (in the Kumaun Himalaya), and indeed the likeness is striking; but subsequent opportunities enabled me to identify the Kojak shales with the Ghaziaband beds.

It would thus seem as if the Ranikot beds, which occupy about the same relative horizon as do the Kojak shales, are a fossiliferous facies of this flysch-like series of beds. Both deposits betoken rather the nearness of an old coastline or a shallow, favourable to rich fucoid growths. Many of the rocks of the eastern Alps and also of the newly acquired territories of the Austrian empire, as would appear from the work of the Austrian geologists in Bosnia and the Herzegovina,[1] bear a similar aspect, and will be found most probably to occupy the same horizon.

How far the Kojak shale group (flysch) and the Ranikot beds

[1] Grundlinien der Geologie von Bosnien Hercegovina Jahrb. K. K. Geol. R. A. XXX Bd., 1880.

assimilate at other localities I cannot say, not having been able to go far beyond the road.

Lieutenant W. W. Robinson, R.E., was good enough to furnish me with a few particulars regarding the structural features of the Gwaja pass, south of the Kojak. The same shales and sandstones which form the latter also prevail at the Gwaja pass; in fact, the Amran range is mainly built up of a synclinal fold of these rocks. But near the Gwaja pass, at or near the line of the Ispintáza river, the shales rest on hornblendic granite. This is an important feature; as will be seen further on, the granite of this region is of late cretacaous times, and thus the features of the Gwaja pass lend additional proofs that the Kojak Amran shales are of post-cretaceous or eocene age.

Cretaceous series.

At the base of the eocene formation in Biluchistan and the adjoining parts of Afghanistan the cretaceous series appears in great thickness, mostly represented by hard limestones.

The Bolan pass from Dozan to Darwaza and the greater part of the Quetta valley with the neighbouring hills, are composed of cretaceous rocks.

The base of the Kojak-Amran range is also, as shown before, of cretaceous age; and westwards of the Amran range a wide area of cretaceous rocks extends. Between this range and the river Helmand I met with no younger rock; and it is very probable, as far as I could judge from the scanty information I could obtain, that this feature holds good to as far as Herat.

In the sections near Quetta I could distinguish the following groups in descending order:—

6. Passage beds; shales and limestones.
5. Liver-coloured shales and grits, trap.
4. Hard dark limestone.
3. Red, white, and variegated shales and argillaceous limestones.
2. Hard grey limestone; *Inoceramus*, corals.
1. Hippuritic limestone.

In the neighbourhood of Kandahar the succession of beds is different, and I found:—

2. Hippuritic limestone with
   a. Hornblendic granite. *b*. Trap.
1. Trappoid beds and grits.

a. Biluchistan sections.—It is very probable that at the time when the lower eocene rocks were deposited the cretaceous series was already beginning to form huge folds and domes, the latter no doubt brought about by pressure at more or less right angles to the one which eventually lifted the area above the level of the sea.

It is one of these domes the remains of which are still seen in the neighbourhood of Quetta. As the rocks in that locality are typical for the Bolan pass also, I will describe the section which I found near Quetta.

West of Kari, in the Quetta valley, a small stream, which runs nearly at right angles to the strike of the rocks, has exposed a good section from the lower eocene Alveolina-limestone into the Inoceramus-limestone (2 of figs. 7 and 8 and of the list given on page 34), (see also profile 1, Plate IV).

Overlying beds: Alveolina limestone.

Corresponding with the numbers of figs. 7 and 8.	
6.	11. Flaggy grey limestone alternating with shaly beds and massive limestone.
	10. Limestone in thick masses, filled with small bivalves *Ostrea*, etc., with coral banks, resembling *Lithodendron*.
	9. Beds of grits and limestone with oolitic structure.
	8. Hard flaggy and calcareous sandstone.
5.	7. Liver-coloured shales and grits with traces of small *Ostrea*; the shales are evidently made up of trappean material.
4.	6. Black hard dolomitic limestone of great thickness, and showing only traces of bedding, dip 40° N. W., filled with small *Ostrea*.
3.	5. White flaggy limestone, breaking with conchoidal fracture.
	4. Purplish red calcareous shales and argillaceous limestones.
	3. Thin-bedded argillaceous limestone, light-coloured, alternating with grey calcareous shales, dip 45° N. W.
	2. Flaggy concretionary argillaceous limestone beds, light red coloured, alternating with red, friable shales.
2.	1. Massive grey limestone in thick beds, showing sections here and there of corals and *Inoceramus*. Great thickness.

This same series of rocks holds good over the whole of the area east of the Ghaziaband range. It can be seen in clear succession on the east slope of the Takatu hillmass, as far as I could ascertain during a hurried ride into the rocky valley bounding the group of hills in that direction. The dark coloured trappoid bed 7 (4 in fig. 5) and the lower bright red and white coloured shales and argillaceous limestones (3 in the same figure) may be seen from far off and mark all the rest. I have shown this feature in fig. 5, page 29; a similar good section may be obtained between Sir-i-Bolan and Darwaza. There the trappoid band, dark green and brown in colour, is replaced and supplemented in places by a dark basaltic rock, and both these rocks form a landmark in making out the structural features of the district.

The lofty bare hills east of Quetta, which are not named on the map, consist of grey, hard, fine-grained limestone beds; immediately at the base they are seen to dip below the level of the Quetta valley; but near the top of the range the beds are seen to suddenly dip in the opposite direction, towards the east, the change resulting in a partial fracture along the strike of the rocks. This fracture has been further deepened and widened by a small mountain stream, which now exposes the lower limestone beds of the series (1 in sections 7 and 8), which contains, besides sections of corals and indistinct bivalves, hippurites in numbers, though owing to the hardness of the rock it is almost impossible to obtain more than sections through these fossils. The upper limestone beds (2) contain numerous corals and large *Inocerami*, which fill whole banks. I was shown a badly preserved specimen of an ammonite from this hill, but I do not know from which part it was derived. The appearance suggested the lighter coloured limestone (2) which also contains the main mass of the Inoceramus-banks.

Any one only examining the section across the valley between Quetta and Kari (fig. 7) would naturally suppose that the light coloured limestones of the hills east of Quetta underlie the limestone (2) west of Kari; it is only after seeing the continuation of the section both to the north and south towards Sir-i-ab that the structural features become

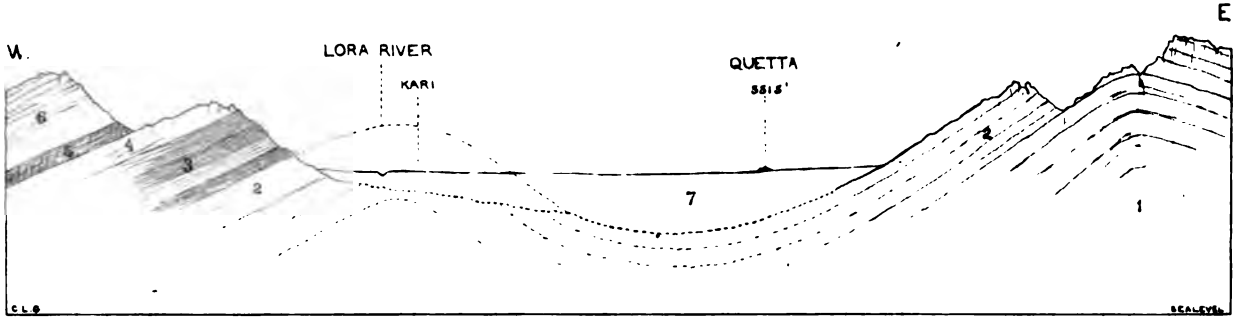


Fig. 7. SECTION (A) ACROSS THE QUETTA VALLEY.

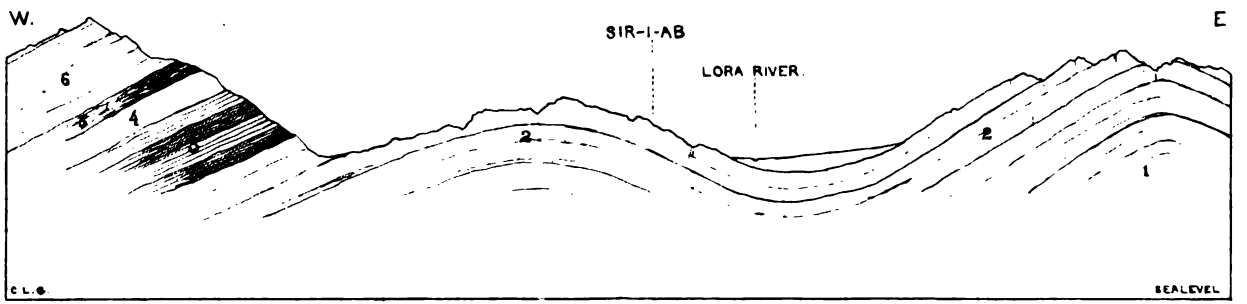


Fig. 8.—Section (B) across the Quetta Valley.

1. Hippuritic limestone. 2. Ditto, with Inoceramus. 3. Variegated flags and shales. 4. Ostrea-limestone. 5. Trap and liver-coloured shales. 6. Passage beds below Alveolina limestone.

clearly intelligible. About 2 miles south of Sir-i-ab the central arch, worn away near Quetta, is still left intact, as shown in fig. 8, and there the bedding is clearly visible.

Beyond it also appears the beginning of another double fold, forming a domelike structure; this feature is clearly seen on the road from Sir-i-ab to Darwaza, from which point the sketch, profile 2 of Plate IV, is taken, showing the synclinal flexure between the two great folds. The hill on the right side (north) is the remains of the Quetta fold, shown in fig. 8 (text), but seen in the profile of Plate IV more or less in the line of strike.

The valley of Quetta is therefore really a trough formed by the natural flexure of the cretaceous limestone beds. The basin so produced is now filled with alluvial deposits, but this of course does not interfere with the collection of water, which gradually fills the basin and may now be found within a few feet of the surface soil. Unless some mode of draining the valley is carried out, the place is likely to be very unhealthy when once it becomes a great military centre.

I have given views of the hills about Quetta in profiles 1 and 2 of pl. IV; the dark coloured band 3 serves as a landmark for the geological surveyor. It is the black hard limestone 4 of figs. 7 and 8 on page 37, which is immediately overlaid by the liver-coloured shales and trap. This dark band with the dark green or brown trappoid shales and trap above, is visible for many miles along the slope of the hill ranges north and west of Quetta, and also in the cretaceous series of the Bolan pass between Darwaza and Dozan. Along the hill range west of Quetta the Inoceramus-limestone (1) is exposed along the base of the range, increasing gradually in thickness towards the south (left in picture); the intermediate space is occupied by the argillaceous shales and limestones of red and white colour (2 to 5 in the list page 35). The further hill range marked 4 in the profile is made up of beds 8 to 11 of the above list, mostly hard limestones. Beyond that range in the distance is shown the Ghaziaband range with nummulitic limestones on the top and Gáj beds skirting it. The north margin of the Quetta valley is composed of the

heights and ranges of which the Takatu (14,000 feet) is the crowning point. In the annexed figure 7 I give the profile of this mountain mass. It is the continuation of the great Quetta fold, the centre only of which is seen near the right margin of the drawing. The base of the fold is composed of cretaceous rocks, of the same succession as described on page 36, but these rocks are mostly denuded and form the lower hills between the giants Takatu and the opposite high eastern hills; the highest part of the ranges in both instances are eocene (nummulitic).

The only other ground where I have found cretaceous rocks in Biluchistan is in the upper Bolan, which is entirely composed of them. Between Darwaza and Dozan nothing else is seen but rocks belonging to this group contorted into many folds. The succession of rocks is the same in every particular as already described, and in the magnificent cliff sections between Darwaza and Dozan this is shown to perfection. Especially remarkable is the constancy of the trappean band (7) with liver-coloured shales, which is seen in a thickness not exceeding 30 or 40 feet running along for miles. Between Dozan and Sir-i-Bolan the strata of this series gradually dip south-east and disappear beneath the hard, grey, Alveolina-limestone of the lower eocene formation.

b. Afghanistan.—It only remains now to notice the cretaceous series as I found it in Afghanistan. Here I must begin with a rock, which, although I include it amongst the cretaceous series, must remain doubtful as long as no fossils are found in it. This is a sandy greenish-grey limestone, containing apparently some trappean material, which forms the low hills skirting the Amran range along the eastern slope. The rock, whose strata are contorted into many and complicated folds, forms a belt of varying width along the Kojak-Amran range, as far as I could follow in person or see with the aid of glasses. The general dip is towards the Amran range and below it. I have shown the position (3) in figure 8; there it occurs near Killa Abdulla south-east of the Kojak pass. It is very probable that this complex of beds, amongst which trappean

material is easily recognised, represents the liver-coloured shales of the section near Quetta, or, in other words, the olive (Cardita beaumonti) group of Sind and the Salt-range. The position immediately below the eocene group would not interfere with this supposition.

The country lying between the Kojak pass and Kandahar is more or less nothing but *dasht*, a stony desert, only here and there covered in good (rainy) years with a poor grass vegetation. Out of this great waste protrude at certain intervals what seems at first sight isolated hills and groups of hills, all more or less parallel to each other, but in fact continuations of the great spurs, running towards the south-west from the Gilzai highlands and the Safed Koh. Travelling from the Kojak towards Kandahar one has to cross or pass in succession the hills of Spinbaldak, of Dobrai, of Melkarez (Takht-i-pul), of Abdul Rahman, of Mandi Hissar, and lastly, those of Kandahar. All these ranges are composed of hippuritic limestone with igneous rocks; it is mostly a light grey, sometimes almost black, hard limestone, here and there with reddish patches and cellular structure. It always weathers into a honeycombed surface, which in spite of the steep slopes makes the ascent of all these hills a very easy matter. The limestone is traversed in all directions by a series of dykes and intrusive sheets of igneous rocks, presently to be described, which have altered the rock so completely in some places that the recognition would be impossible, were it not for the stratification which is always preserved, and which enables the tracing of the same bed over a considerable area.

Structurally these parallel chains are nothing else but a series of north-east to south-west folds and minor plications of the cretaceous series.

The view plate V represents some of these isolated ranges surrounded by *dasht*, which may be seen from the summit of the Kojak pass. The rock in the fore-ground, which is part of the Kojak-Amran range, is composed of the eocene flysch-like shales and sandstones. The hills in the distance are all hippuritic limestone with igneous rocks. But an idea may be formed of the barrenness and dreariness of the pic-

ture presented by these bare limestone hills in an apparently interminable desert, in which no villages afford a relief to the eye.

The hills between the Kojak and Mandi Hissar offer little of interest; in places they are considerably altered by subsequent eruptions of igneous rocks, but those which I had the opportunity of crossing were too detached to offer subjects for geological observations. If I can trust to an observation made with a very good telescope, I believe there are younger rocks, eocene probably, which overlap the cretaceous series north and north-east of Melkarez, in the range skirting the Arghastán river.

The cretaceous rocks of Kandahar are of the highest interest mineralogically. When I first camè up to Kandahar I was struck by the similarity of the limestones there with certain limestones and other rocks of the Kumaun Himalayas, of which the Chína (Naini Tal) limestone is the representative. For some months I believed therefore that the Kandahar limestone was palæozoic. About 20 to 22 miles west of Kandahar, near Karez-i-Salim, there is an isolated hill of light-coloured limestone full of hippurites and other cretaceous fossils. My thanks are due to Lieutenant-Colonel Leach, R.E., V.C., who first drew my attention to the existence of this cretaceous locality. But in spite of that I could not identify this light-coloured fossiliferous rock with the dark, almost black, limestone, devoid of any fossils and altered by igneous rocks in places to a sort of gabbro.

Fortunately, on one of the last days which I spent in Kandahar after the siege was raised, I discovered a few fragments, though undoubted ones, of hippurites in the range west of Kandahar, near which the old city of Kandahar was built. This discovery settles the age of the whole range as cretaceous.

The Kandahar-Argandab range is also of great interest, as there alone I have seen what I might call the base of the hippuritic limestone.

Certain beds are exposed in the valley north of Kandahar, near the

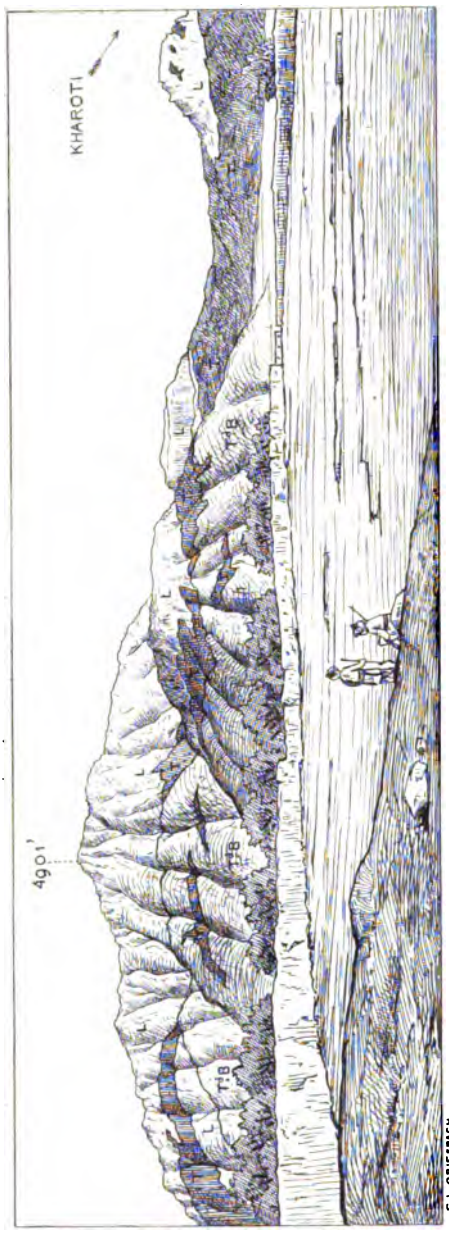


Fig. 6. Profile of the Koktoran range from near Sinjori.
Td. B.—Trappoid beds. L.—Hippuritic limestone. T.—Trap intrusions.

Kotal-i-Murcha which differ considerably from the overlying hippuritic limestone; the same beds are *in situ* along the west slope of the Kokaran hill (fig. 9), where they are found in considerable thickness.

It is a matter of great difficulty to distinguish between the altered beds of the superincumbent hippuritic limestone and the lower beds, which also are greatly disturbed and altered by subsequent eruptions of trap. But I could make out that there are three different rocks represented in this lower cretaceous series. In descending order:—

3. A shaly sandstone, made up more or less of trappean material.

2. Bright-coloured green and densely red shales with thin sandstone beds of trappean substance.

1. Conglomerate, coarse and in great thickness, almost entirely made up of pebbles of trap, and cemented together by a trappean though calcareous matrix.

These 'trappoid beds' are of great importance, because they are traversed in all directions by numerous

quartz veins and reefs, one of which, 3 miles north of Kandahar, has yielded gold.

The sequence of beds and their geological boundaries are now very difficult to determine owing to the subsequent disturbance and alteration by numerous trap dykes which penetrate the whole of the cretaceous formation.

At Kokaran may be seen resting on this system of lower rocks huge masses of fine-grained, hard, grey limestone; it is the same rock which between Chaman and the Helmand forms nearly all the intervening ranges of hills. Fragments of hippurites, corals, and other remains of cretaceous fossils may be collected in abundance in many localities between those limits; the hippuritic cliffs near Melkarez on the road to Kandahar proved especially rich in remains of hippurites. The limestone hill near Karez-i-Salim, before mentioned, is full of remains; but owing to the hardness of the rock, which is in places completely converted into a crystalline limestone, it is very difficult to obtain well-preserved specimens. About 4 miles north of Karez-i-Salim may be seen the continuation of this hippuritic formation. I found that the high jagged hill (6,096 feet) which may be seen near the north side of the east entrance to the Maiwand pass, and dividing this from the Tangli pass, is composed of the same white crystalline limestone, here and there showing red patches and lines and greatly altered by the igneous rocks (granite and trap) which penetrate it in all directions (see fig. 10). This crystalline limestone is greatly used by the natives of Kandahar for ornamental purposes as marble, and may be seen in several shrines and other devotional buildings in Kandahar, as for instance in the tomb of Ahmed Shah.

The fig. 10 represents this hill mass as seen between the roads which lead on one side to the Maiwand pass and on the other to the Tangli pass. The granitic intrusions and subsequent trap outbursts are very conspicuous from a great distance, and I shall have to allude to them again subsequently.

Passing through the Maiwand pass, which crosses the Maiwand-

Fig. 10. Profile of hills near the Tangil pass.
G.—Granitic rock intrusions in hippuritic limestone. T.—Dekkan trap.

Argandab range, and which is made up of igneous (cretaceous) rocks, I came upon a narrow strip of crystalline limestone, now worn into low hills, which skirt this range on its western slope (see Plate X, and profile 1, Plate XI). The crystalline limestone found there is a beautiful, fine-grained variety, with here and there patches of reddish colour, and is remarkable for the numerous intrusions of hornblendic granite which it contains, and which I have drawn in the figures of Plate X and Plate XI.

North of Maiwand rises the high (about 8,000 feet) range of the Shah Makhsud, which has a gradual and gentle dip towards the north and north-west, showing a steep scarp towards the east and south.

Further west follow the parallel chains of the Garmao and the Sangbur hills, resembling in their general character and composition the Shah Makhsud range.

Both ranges, so far as I was able to examine them, consist of hippuritic limestone beds, which have a general dip towards the

north and north-west, and are scarped towards the east and south. The beds are almost entirely composed of light-coloured grey and bluish limestones of the same character as the cretaceous limestone seen elsewhere; here and there concretionary beds and fine conglomerates are intercalated between the fine-grained limestones, of the same character as those concretionary beds (Grossoolith of some of the European limestones) seen in the Bolan pass, near Darwaza and Dozan and also in the hills east of Quetta.

The time spent in those hills was too much curtailed for me to have been successful in the finding of fossils, but I have no difficulty or hesitation in identifying the rocks composing them with the Kandahar hippuritic limestone formation.

These massive ranges possess one remarkable and interesting feature, and that is the formation of cross-valleys; one of the most beautiful examples of this is the valley of the Malmand pass. The watershed of this valley is now the *kotal* (small hill) near the east entrance of the pass, formed of trap. The water of the Malmand rivulet takes its rise near this small kotal, winds through the mighty mass of limestone composing the Garmao hills, more or less at right angles to the direction of the range, and after scooping out a narrow gorge, known as the Malmand pass, emerges at last somewhere in the valley of the Helmand, to which river system it belongs.

From the accounts received by natives and descriptive notes of travellers, as for instance Captain Thomas Hutton,[1] it appears that also further north the Shah Makhsud range consists of the same hippuritic limestone, converted locally into a crystalline rock; a similar formation with associated granite may be found near the west entrance to the Siah Sang pass, leading from the Argandab into the upper Khakrez valley. This limestone is evidently but a continuation of the Maiwand pass limestone with granite intrusions.

Comparison with other areas.—Comparing South Afghanistan with the countries lying west and north-west of it, it becomes at once apparent

[1] Notes on the Geology and Mineralogy of Afghanistan, Cal. Journ. of Nat. Hist., Vol. VI, p. 562.

that at least from the beginning of the cretaceous period there must have existed the closest connection of the tracts lying between the south-east of Europe and the Indus, and that this connection, that is to say, the uniformity of the physical conditions over the whole area, must have lasted into the lower tertiary period at least.

To begin with the cretaceous. In South Hungary, the Banat, the new Austrian territories of Bosnia and Herzegovina, and the Adriatic provinces cretaceous (hippuritic) limestones prevail to a large extent. And between that area and Afghanistan, over a wide extent of Persia the same hippuritic limestones prevail with but few interruptions.

The features of this formation are very remarkable, and it retains its character uniformly more or less over the entire area.

In the Banat this formation is accompanied by the presence of syenitic granite rock, which Cotta named Banatite, but which others[1] have since grouped into different varieties. The contact zone of this granitic rock and the hippuritic limestone, which is in those places mostly converted into a crystalline rock, is remarkable for yielding various ores, amongst them copper, gold, argentiferous lead ores and iron.

Similar are the localities in the neighbourhood of Rézbánya in Hungary, where the same ores are obtained.[2]

I may here mention that the gold localities in the Banat also yield minerals of cobalt and nickel, and that in some places (Oravieza)[3] they are the leading minerals of the auriferous area.

So in Afghanistan the gold-bearing rock occurs near the junction of the cretaceous group and the igneous zone, and minerals of both cobalt and nickel occur in traces all over the rock.

[1] Niedzwiedzki: Jahrb, k. k. Geol. Reichsanst., 1873, Min. Mitth., p. 255.
Szabo: Sitz. Ungar. Geol. Gesell., 25th Febr. 1875.

[2] G. Marka: Jahrb. k. k. Geol. Reichstants. 1869, p. 299.
Prof. Peters: Sitz. Ber. k. Akad. Wiss. Bd. XLIII, p. 385.
and Bd. XLIV. p. 81.
Posepny: Geogn. Montan. Studie der Erzlagerstätten von Rezbanya, Budapest, 1864, etc. etc.

[3] G. Marka: *op. cit.*, p. 317.

In Greece, Theo. Fuchs[1] has found that the base of the hippuritic limestone consists of slate-like beds, sandstones and trappoid beds, with serpentines, which belong to the cretaceous series. The trappoid beds of Afghanistan may be compared to this series. The hippuritic limestone of Greece is locally altered into a crystalline variety, used as statuary marble.

Mr. W. T. Blanford[2] mentions the probability of certain granitoid and altered rocks of Persia being of cretaceous age, which also Mr. K. Loftus[3] admits for certain rocks of the series.

Such features seem also to exist on the south-east coast of Arabia,[4] for there granitic rocks are found in the lower cretaceous limestone, and the section above that horizon apparently is similar to the sections obtained in Afghanistan.

It would thus appear that the cretaceous formation, especially the hippuritic facies of it, was marked over a wide area, extending from south-east Europe to the Indus, by the outbursts of granitic rocks, which caused the partial alteration of the hippuritic limestone into crystalline marble along which contact zone metalliferous deposits were formed.

IGNEOUS ROCKS.

Lower cretaceous: basic rocks.—Near the base of the hippuritic limestone, where such is exposed, I noticed beds of shales and sandstones associated with conglomerates, all of which, and especially the latter, are more or less made up of trappean material. I have noticed these beds before, page 43; the conglomerate is especially remarkable, composed of trap pebbles cemented together by a trappean ash matrix, locally calcareous. These trappoid beds at the base of the cretaceous limestone extend, as far as I could ascertain, from near the head of the Kotal-i-Murcha valley, north of Kandahar city, to near the Pir Paimal,

[1] Sitz. Ber. k. Akad. Wissensch. Bd. LXXIII, 1876, p. 338. Dr. Neumayr: Verh. k. k. Geol. Reichsanst., 1877, p. 217.

[2] Eastern Persia, London, 1876, p. 454.

[3] Quart. J. Geol. Soc., 1855, Vol. XI. p. 247.

[4] H. J. Carter: J. Bomb. R. A. S., IV., p. 21.

where they form the lower eastern slopes of these hills (see Pl. VI. and map of Kandahar). Near the Pir Paimal the range is interrupted, but there are indications in the gap so formed, especially near the village of Gundigan, that the rock is present along that line, though now denuded and mostly covered up by recent alluvial deposits. But in the Kokaran range, between the villages of Kokaran and Badwán, the lower trappoid beds are in strong force, and form the whole of the lower west slope of the range (see fig. 9, p. 42).

I think it is highly probable that *some* of the trap found near and below the south slope of the Shah Makhsud range belongs to this formation of contemporaneous lower cretaceous trap, though it is everywhere very difficult to distinguish between the older trap formation and the subsequent flows and eruptions of upper cretaceous traps.

But there is sufficient evidence that there is an older formation of basic rocks which preceded the deposition of the widespread hippuritic limestone, and this is especially of interest when we compare the Afghan area with allied regions to the north-west,—Persia, Greece, and the Banat.

Upper cretaceous: acid rocks. Syenitic granite.—Of far greater structural importance is a granitic rock which belongs to the younger cretaceous series, and which forms high ranges in Southern Afghanistan.

The chief localities where I have met with this granite or know it to exist are (1) the dividing range between the Khakrez and Argandab valleys, (2) the ranges about Dabrai and Gatai, and (3) in the Kojak-Amran range near the Gwaja pass.

1. The Khakrez Argandab hills.—I noticed this rock there during my first trip to Maiwand. Going through the Maiwand pass I met first huge masses of trap which traverse the cretaceous limestone near Karez-i-Salim and north of it in all directions. Near the highest point in the pass I suddenly came upon a granitic rock, into which the trap had freely penetrated as dykes.

The granite forms high and fantastic shaped rocks, decomposing here and there in concentic structure. Close to the west entrance to the Maiwand pass I came again upon the crystalline limestone, described

in page 44. This limestone is traversed in every direction by dykes and veins of the syenitic granite, and no doubt to this fact may be ascribed the crystalline and altered structure of the limestone.

I have shown in the first profile on Pl. X the west entrance to the Maiwand pass, with its two characteristic white marble hills (1); the bare slopes of which show the intrusions of the dark reddish syenitic rock (2) from afar off. The range behind is entirely composed of this same granite; only the eastern slope of it is formed of trap, which also penetrates in dykes and veins into the granite. A better view of this fine example of intrusion is afforded in profile 1 of Pl. XI, which shows the northern one of the marble hills near the entrance to the Maiwand pass with its numerous intrusions of granite.

In places the granite forms long dykes, varying from several hundred feet to intrusions of a quarter of an inch thickness in the limestone. In others only the outcrops of necks of irregular shape are shown. The entire mass of the limestone is altered to a crystalline structure, and near the contact with the granite the limestone is coloured reddish. The granite itself is a rather coarse-grained variety, containing felspar (pink orthoclase and white oligoclase) with quartz and hornblende. This is the commonest variety, but in some places it is a fine-grained mixture of felspar quartz and hornblende, with some larger felspar crystals embedded, then resembling porphyritic syenite. Near the west entrance to the Maiwand pass I noticed numerous veins and dykes in the syenitic granite mass, composed mostly of a porphyritic mass, evidently closely related to the former. They show large pink orthoclase crystals embedded in a matrix, the constituents of which are obscure but felsitic, with a few fine particles of quartz and hornblende visible. Others show a dense grey felspatic matrix. Some of these felsitic veins are not thicker than half an inch; others again are of considerable width and extent.

I believe that these rocks will be found to resemble closely the eruptive rocks of the Banat in Hungary; there also syenite-like rocks have been erupted through the cretaceous series, showing a similar transform-

ation of the hippuritic limestone into finely crystalline marble; various ores (copper, lead, silver, and gold) are met with in the altered contact zone, exactly in the same manner as they are found in Southern Afghanistan.

Besides these porphyritic veins, the later trap rocks, under which term I include the various basic rocks in connection with the widely extended Deccan trap spreads, form masses and dykes of varying dimensions in the granite. In profile 2 of Pl. XI I have given a camera view of the trap dykes in the syenitic granite near Lalak in the lower Khakrez valley. I believe that the porphyritic rocks belong to the same period of eruption as the traps, and that the change in mineralogical character is due to the vicinity of the granitic rocks, in the same way as the serpentinous masses in the basic traps are due to the contact with the cretaceous limestone.

As already noticed, the hill mass north of Karez-i-Salim is a fine example of the granitic intrusion in the hippuritic limestone (see fig. 10, page 44), where huge masses of the same hornblendic granite appear in the finely crystalline cretaceous limestone cliff and are visible from many miles away. The Darra Tangli was the most northern portion of the Argandab-Khakrez range which I was enabled to cross. It consists entirely of the hornblendic granite with a few subordinate dykes and veins of felsitic porphyry and trap. From accounts received from others (for instance, Lieutenant-Colonel Leach, R.E.) a similar rock prevails to the east of this region in the hills north of Khwaja Mulk in the upper Argandab; indeed, as much might be inferred from rolled fragments of granitic rock found in the Argandab river deposits.

2. Hills about Dabrai and Gatai.—The road between Melkarez and Dabrai leads over a low pass formed of trap rocks cropping out from beneath hippuritic limestone, which forms high cliffs on either side of the pass. Immediately on descending the kotal towards Dabrai I found syenitic granite of precisely the same character as that of Maiwand. It forms the low hills encircling the small plain, on which stands Dabrai fort. As is the case at Maiwand, the granite is

traversed by parallel veins or dykes of trap which, being able to withstand disintegration better than the granite, forms protruding masses and walls in the latter rock, visible from afar off.

About 2 miles west of Gatai the same granite forms the low ridge of that locality; from afar the peculiar rounded outlines of the granite distinguish it from the bolder forms of the cretaceous limestone of Melkarez and Takht-i-pul.

3. Kojak Amran range near the Gwaja pass.—Lieutenant W. W. Robinson, R.E., who had visited the Amran range in the neighbourhood of the Gwaja pass, informs me that the west slope of the pass consists of syenitic granite, with white and light pink felspar, and large crystals of the same mineral enclosed in the mass.[1] In places the rock changes into a hornblendic rock (quartz and hornblende). The whole is traversed by a porphyritic rock in veins and dykes.

The Amran range east of the Spintaza river is made up of the shales. Mr. Robinson could see no mineralogical change in the shales near the contact with the granite, and asserts that they are identical with the Kojak shales. I have therefore coloured them on my map as such (eocene).

Upper cretaceous: Basic rocks.—The commonest forms of basic rock met with in Southern Afghanistan and in the Bolan-Quetta area are the complex of basaltic and serpentinous rocks known under the name of Deccan trap, and their outburst belongs to the upper cretaceous period. The best clue to the understanding of the latter question I found in the sections about Quetta and the Bolan, where I got an uninterrupted chain of beds from the hippuritic to the upper tertiary. The only trace of igneous rocks in this series[2] I found in the upper cretaceous, in the form of a contemporaneous bed of trap of small thickness, but wide lateral extension. There can be no doubt that this bed of trap represents the trap horizon of Western Sind, described by W. T. Blanford,[3]

[1] Also noticed by Captain Hutton. Calcutta Journal Natural History, VI., p. 562.

[2] The lowest cretaceous (trappoid) beds are not exposed in the Quetta or Bolan sections.

[3] Mem. Geo. Surv. of I., Vol. XVII., pt. 1.

and thus is also a representative of the Decean trap of India; and I believe that the enormous outbursts of trap in the neighbourhood of Melkarez, Kandahar, and the Shah Makhsud range belong also to this horizon. Lithologically it is a basaltic rock, mostly very dense black or dark green in colour; many varieties are more or less crystalline in structure, and then frequently porphyritic. A common variety of this kind shows a homogeneous reddish-brown felspathic matrix with large tabular white felspar crystals and masses of olivine embedded in it. Such, for instance, I found in the trap hills near Sinjori in the Argandab valley and in the valley of Murcha, north of Kandahar.

Another form of the same formation resembles almost a melaphyre of a dense homogeneous texture with beds of amygdaloidal structure.

North and east of the gold mine, 3 miles north of Kandahar, I found this rock in great force. Some of the vesicular hollows of the amygdaloidal rock are filled with achates (agates), and others contain beautiful zeolitic crystals. But by far the most frequent rock is a dense basaltic variety, here and there decomposed into a crumbling green earth. Near the contact with the limestone of the cretaceous series, the basalt is altered into a semi-crystalline rock; it also changes into a serpentinous rock, very soft and calcareous, with veins and lumps of chrysotile (fibrous serpentine) of light green or yellowish colour which the natives of Kandahar use for the manufacture of the more inferior kinds of beads for rosaries; the beautiful bright green and yellowish coloured crystals of chrysolite (clear olivine) which are found in the denser varieties of the basalt furnish material for the more expensive kinds of beads and articles of jewellery. Where the trap forms hills, the rock is distinctly bedded; numerous veins and dykes of most varying thickness traverse the adjoining cretaceous rocks.

In one locality at least I believe I detected a clear example of the remains of an old volcanic centre. The valley formed on the west by the Kokaran Badwán hill range and on the east by the hill range of old Kandahar, I believe encloses such a volcanic centre. On both sides of the valley the bases of the ranges are formed of trap, dipping away

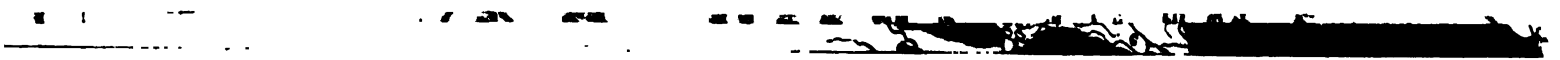
from the centre at a low angle. The base of the valley, now levelled by denudation, shows trap beneath the covering of post-tertiary gravels. Trap dykes and veins of from hundreds of feet in thickness to fine veins of the sixteenth of an inch in thickness traverse the neighbouring limestone and shales, changing the latter into a semi-metamorphic rock.

The hills around this valley afford a good opportunity to study the effects and mode of intrusion. I reproduce a few camera drawings which illustrate these features.

The view from the Edgah wall of Kandahar (Pl. VI) shows the distribution of the trap amongst the limestone. The hill range bounding the Murcha valley on its eastern side is more or less composed of trap, with a few isolated patches and remnants (see map of Kandahar) of the cretaceous formation highly altered by the surrounding igneous rock. The dark ridge (4705 feet) north of Kandahar is formed of amygdaloidal trap, which stretches far to the north-east. Towards the south-west the trap extends in low rounded hills skirting the base of the range on its eastern side, and forming a widely spread but low hill group at the base of the Baba Wali Kotal, well known during the siege of Kandahar as the hill on which stood one of Ayoub Khan's cavalry pickets. Numerous small veins and dykes of trap reach into the surrounding limestone cliffs.

But by far the most instructive locality for studying the relations of the trap and the hippuritic limestone is afforded by the range which extends from Gundigan in a south-westerly direction towards Ashu Khan, and which I generally term the Kokaran range. I have given examples of this range in Plates VII, VIII, IX, and figs. 9 and 11.

Profile 1, Plate VIII, represents the eastern slope of this range, the main mass of which, with its highest point, is composed of hippuritic limestone greatly altered by the trap intrusions. The nature of the trap intrusions and spreads near the base of the hill will be better understood from the figure than I can describe it. The trap enters largely into the structural features of the range, and forms a series of lower rugged hills north and eastward of the Kokaran range. In profile 2 of this plate I



north-to-south direction, up which trap has forced its way, where now lies the deep gully which affords a tolerably easy ascent of the hill. The beds of the hippuritic limestone are seen to dip against this gully (the line of fracture) at more or less right angles. Masses of trap have penetrated the rest of the limestone hill in various directions. Ascending the west slope of the Kokaran hill, many beautiful examples of trap intrusions and contact action may be observed. Such appears at a spot on the west slope, which I have figured in profile 2 of Plate VII. The trap forms these several neck-like intrusions with numerous branches of the minutest dimensions and sharply-defined contact boundaries with the limestone. When following the great trap dyke which fills now the fracture (seen in Plate IX) to the summit of the hill, it is seen to cross a small pass or saddle in the hill group (see profile I, Plate VII) and continue on the other side towards the Kharoti dykes. Here, as elsewhere, the boundaries of the trap are most sharply defined, although the adjoining limestone has undergone a partial change, often into a serpentinous mass. Patches and cliffs of trap may also be seen in the Maiwand hills and in the Shah Makhsud and Garmao valley (see map and Plate X).

Near Zarak and Lalak in the lower Khakrez valley (profile 2, Plate XI), trap dykes are seen to penetrate the syenitic granite locally changing into a prophyritic rock, but where appearing in greater force always preserving the trap character (noticed on page 52).

The same may be said of the trap dykes and spreads near Abdul Rahman, Melkarez and Dabrai on the Kandahar road.

The Quetta-Bolan trap in the upper cretaceous is distinctly interbedded, but does not differ in lithological characters from the Kandahar basic rocks.

NOTES ON THE MINERALS FOUND IN SOUTH AFGHANISTAN, ETC.

Gold.—This metal occurs near Kandahar in quartz veins (reefs) which traverse the zone of contact between the hippuritic limestone and the extensive trap outbursts, and, as far as I could ascertain, are confined to the lower beds of the cretaceous limestone. I have described this

contact zone and the trappoid beds already, pages 43, 48, and 52. The quartz veins vary in thickness from the width of a pencil line to many feet, and most of them have a direction of north-east to south-west. The contact rock is calcareous, and contains a green mineral disseminated through the mass. Mr. F. R. Mallet has examined the rock, and found that "the portion soluble in dilute hydrochloric acid consists mainly of lime and magnesia, with some iron. The insoluble part is chiefly silica and alumina with some iron and magnesia. There is also a trifling amount of copper and a still smaller quantity (scarcely more than a trace) of nickel. The rock appears to be an extremely impure (arenaceous and argillaceous) ferruginous magnesian limestone. The green spots evidently owe their colour to the copper and in part perhaps to the nickel."

Such is the matrix in which appear the auriferous quartz reefs.

About 3 miles north of the city of Kandahar is situated the locality where, during the first months of our occupation of the country, gold was obtained in considerable quantities by a native contractor, who rented the mine from the Kandahar Government. From the accounts furnished me, it appears that the process of extracting the gold with mercury, though very rude, was paying; but the native workers, ignorant as they are of all engineering science, went on blasting the rock with gunpowder, sinking the productive shaft lower and lower, until the sides of it at last gave way burying the miners who were working below. Since then nothing has been done. I give in the frontispiece a view of the mine as it appears at the present moment. It is about 60 to 80 feet deep and about as wide, filled with rubbish from the sides. The auriferous vein, which was yielding gold in good quantities at the time the mine fell in, is mostly covered with blocks from above. Part of it is visible above, and I have marked it with + + + on the view. The portion exposed is only about 2 inches thick, but I was told it thickened lower down to about 2 feet or more, and some of the nuggets of gold obtained were of the size of a man's fist; all the larger nuggets were extracted by hand, and only the rest of the quartz crushed and amalgamated.

I proposed to the late Wali of Kandahar to sink another shaft about 100 yards south of the present position to strike the same or other auriferous veins, but my advise could not be carried into effect owing to the outbreak of hostilities shortly after.

It is highly probable that gold will be found all along the line where I found the trappoid beds more or less altered by the younger traps, and traversed by quartz reefs in profusion. This line of trappoid beds will be found on the larger (1 inch = 1 mile) map of Kandahar in this memoir. It extends from the gold mine to the south-west towards Kokaran, including the Murghan hill. I did what I could to obtain assistance in testing these rocks, but the disturbed condition of the country frustrated all such efforts. It may be that my advice will bear fruit after our troops have withdrawn from Kandahar. Gold is also found and worked in some fashion in the Hazarah country and in various streams of Northern Afghanistan.

Copper.—A poor ore of copper derived from white quartz is found in the Kojak-Amran range. A richer ore is met with in the Shah Makhsud range and is being worked.[1] Copper is also said to have been found near Shah Bellawl about 20 miles south-east of Bela in the province of Lass or Luz in Biluchistan.[2]

It is obtained in considerable quantities from old mines situated in the Ghilzai country in Northern Afghanistan.[3]

Lead and Antimony ores.—Near Bela, according to Captain de la Hoste, antimony and lead ores were also found.

Lead minerals are common in many localities in Southern Afghanistan, and, as far as I could ascertain, they occur near the boundary of the hippuritic limestone with the igneous rocks, granite and traps. Galena is brought from the Shah Makhsud range, the Tirin valley, and is said to occur in quantities in the Hazarah country.

[1] Captain Hutton: Calcutta, Journal Natural History, VI, p. 562.

[2] Captain de la Hoste: Journal, Asiatic Society, IX, p. 30.

[3] Captain Drummond: Journal, Asiatic Society, Bengal, X, 1841.

Sulphuret of antimony is said to occur in the Toba plateau district, north of the Pishin valley.

In Biluchistan lead ores are being worked in somewhat extensive mines situated in the *lower cretaceous limestone* of the Jhalawan district. Mr. Cook[1] mentions that this lead ore (with antimony) occurs near Sekran, about 12 miles west of Khozdar in the Jhalawan province of Biluchistan, the lode is in the dark blue cretaceous limestone, but with it occurs some granite, the relations of which to the limestone is not quite clear. I believe, however, that the ores occur near the contact zone of these two rocks in the same manner as in the Shah Makhsud range.

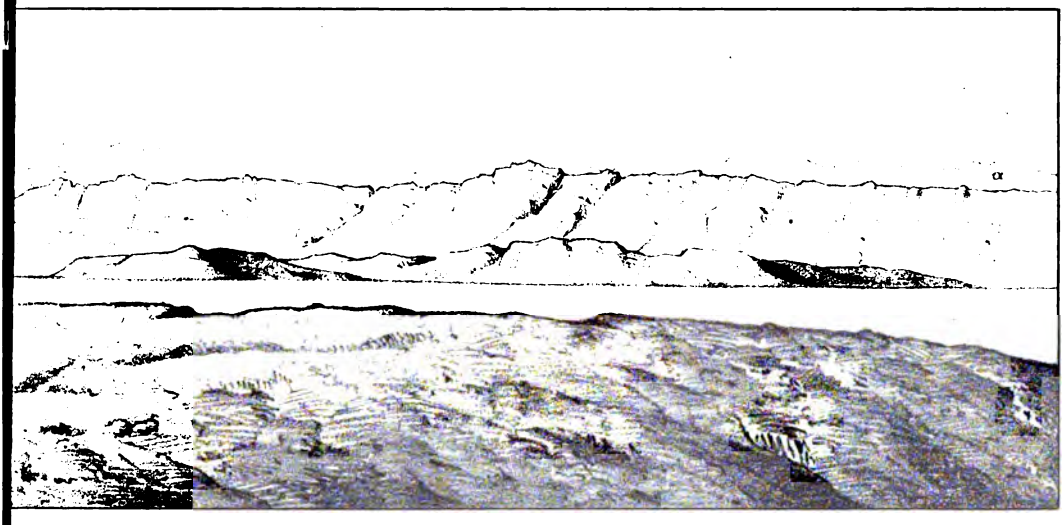
Similar ores are obtained from Banee, in the valley of Greisher (according to Mr. Cook), and there also they are associated with the lower cretaceous limestones. "Lead seems to abound in the Hazarah districts, in Ghorabund of Kohistan, and in Wardak. The lead of the former is of an excellent quality; the latter is inferior and of a harsher character. The one is the sulphuret of lead, and that which I have seen from the Hazarah country occurs in the form of the carbonate. Lead is also stated to be found in Bungesh, and a specimen of it from the Safed Koh has been brought me lately."[2]

Argentiferous galena and native silver are said to occur in the Hazarah country.[3] Argentiferous galena is found near the west entrance of the Siah Sang in the Khakrez valley.

Edrisi[4] describes the rich silver mines of Herat, now said to be disused for want of wood necessary to timber the deep shafts.

Sulphur is obtained from pockets (in upper tertiaries?) in considerable quantities in different parts of Biluchistan. According to Hutton (*op. cit.*) it is found near Sunnee, 40 miles from Bagh, in Biluchistan. Petroleum occurs also in that locality. Another sulphur mine is found near Sibi amongst the Marri hills (Hutton).

[1] Transactions, Medical and Physical Society, Bombay, 1860.
[2] Captain Drummond: Journal, Asiatic Society, Bengal, X, 1841.
[3] Captain Hutton: Cal. Journ. Nat. Hist., VI., p. 562.
[4] Von Ritter: Erdkunde, 8, Bd., p. 242.



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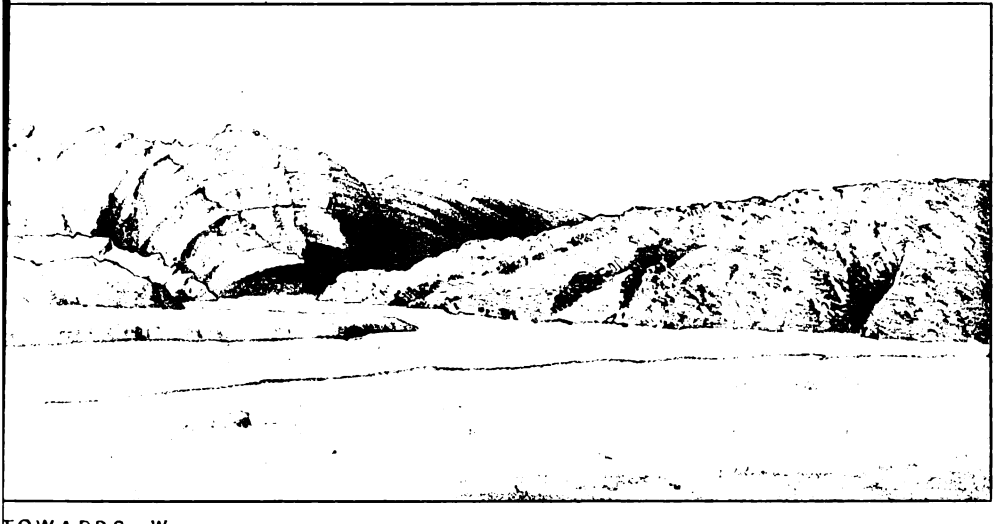

TOWARDS W.

E TO NARI GORGE; *a*, POSTPLIOCENE GRAVELS ETC. *b*, MANCHHARS.

Printed at the Geol. Survey Office.

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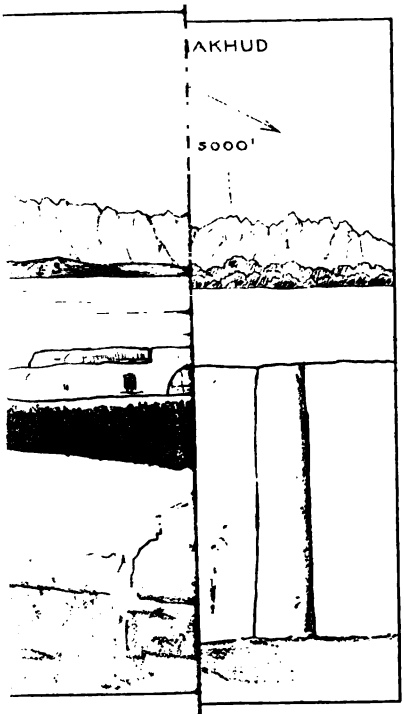
T.I. PL.X.



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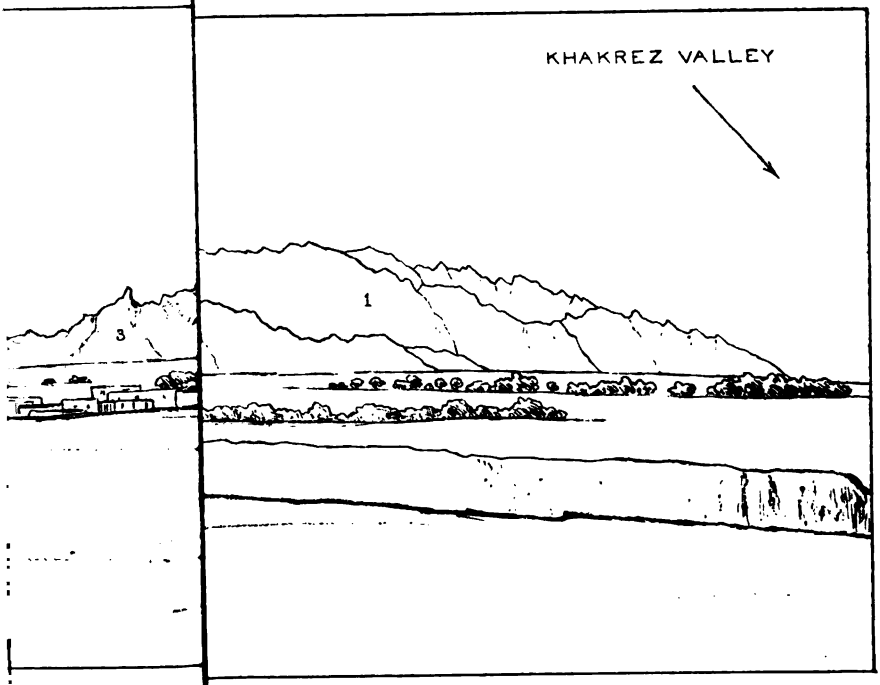

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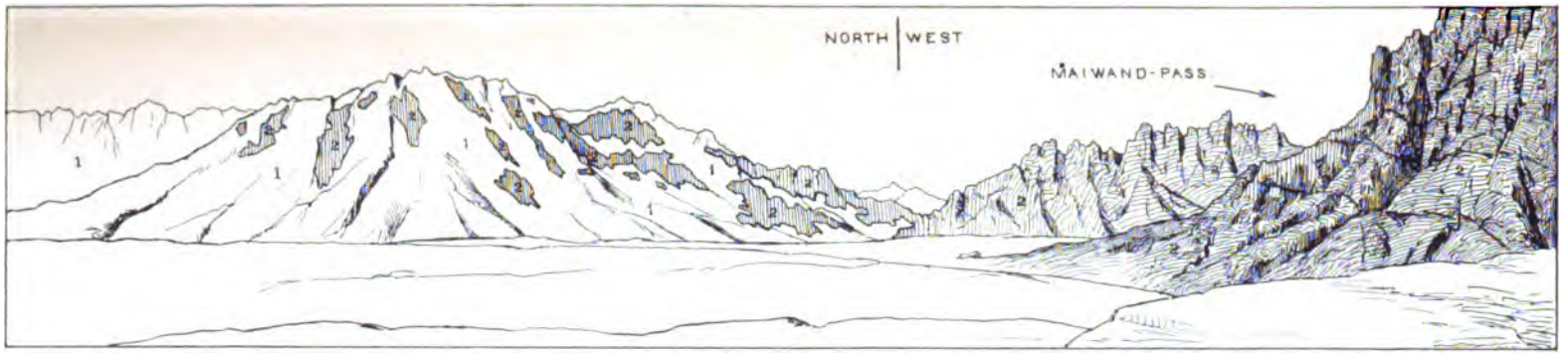
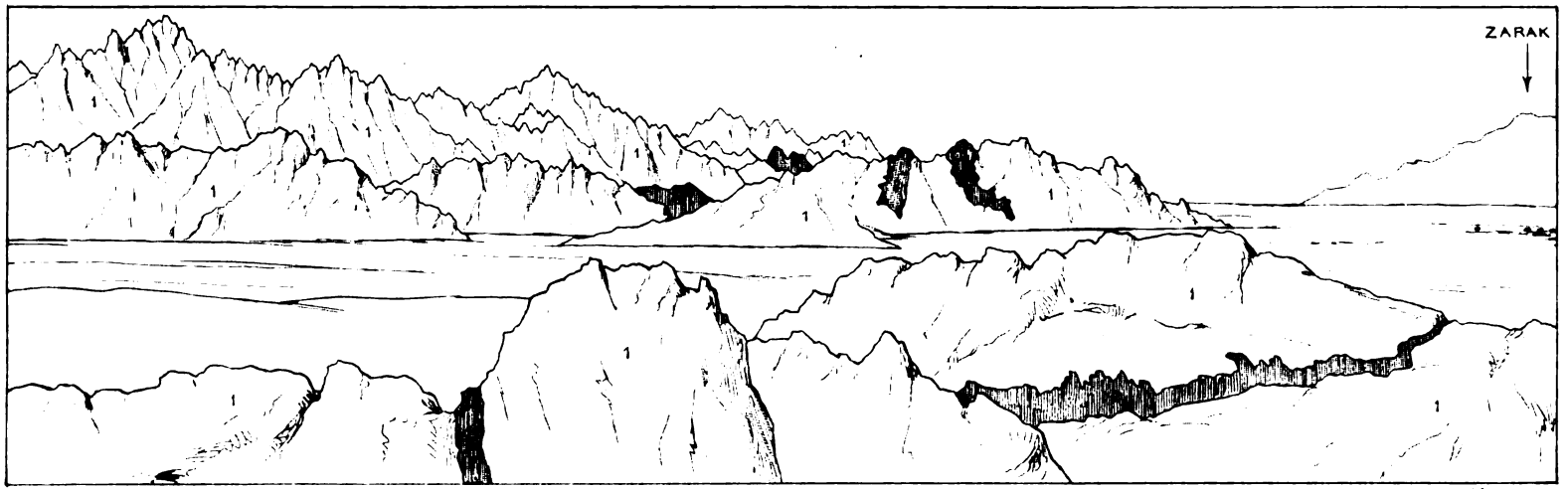


PROFILE 1. GRANITE INTRUSIONS (2) IN HIPPURITIC LIMESTONE (1).
NEAR THE WEST ENTRANCE OF THE MAIWAND PASS.



C.L. GRIESBACH, DEL & LITH. G.S.I. IMP

PROFILE 2. DYKES OF TRAP AND FELSTONE-PORPHYRY IN GRANITIC ROCK
NORTH-EAST OF ZARAK (LOWER KHAKREZ VALLEY).

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

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Map of the Geology of Mánbhúm and part of Singhbhúm.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

GEOLOGY OF THE DISTRICTS OF MÁNBHÚM AND SINGHBHÚM,
by V. BALL, M.A., F.G.S., *Geological Survey of India.*

I.—MÁNBHÚM.

INTRODUCTION.

The following account is intended to fulfil the part of a guide to the Geology of Mánbhúm rather than that of a complete description of the geological formations which occur in the district.

The metamorphic and sub-metamorphic rocks to which these pages more particularly refer—the coal and associated formations having been already described—pass across the boundaries of Mánbhúm, on the north into Birbhúm and Hazáribágh, on the west and south into Lohárdagá and Singhbhúm, and on the east into Bánkúrá and Midnapúr.

In not a few instances phenomena connected with the rocks in Manbhúm can only be interpreted by reference to the adjoining districts in which the relations existing between the formations happen to be more clearly exposed. It follows therefore that, in order to describe them fully, they should be discussed in reference to their extension over a wide area which would not correspond precisely with the limits of particular districts.

Memoirs of the Geological Survey of India, Vol. XVIII, Art. 2.

CHAPTER I.

Previous Notices.

The nearest approach to a general account of the metamorphic and sub-metamorphic rocks which occur in Mánbhúm is to be found in a paper by Colonel J. C. Haughton. This, as its name implies, refers more particularly to the district of Singhbhúm and its mineral resources, but the rocks described are similar to those of Mánbhúm, and the map which is published with the paper includes a considerable portion of the latter district. The other papers quoted below refer simply to the metamorphic rocks seen in the immediate vicinity of the coal-fields or near the route lines traversed by the writers; or they refer merely to special minerals or rocks. Papers referring to the coal-fields only are not included here.

The rocks belonging to formations subsequent in age to those of the metamorphic and sub-metamorphic series which occur in Mánbhúm, are chiefly included within the limits of the Raniganj and Jharia coal-fields, of which full descriptions have already been printed in these memoirs.[1]

Jacquemont Voyage dans L'Inde, 1829.

Apparently the first published notice of the Geology of any portion of this tract is by Victor Jacquemont, who, towards the end of the year 1829, marched from the coal-fields of Raniganj which he had examined, through Beru, Raghunathpur, &c., along the old post road to Hazaribagh. At Beru, he was struck with the non-stratified character of the porphyritic granitic rocks which form picturesque hills there. His account chiefly deals with the general aspects of the country, the manners and customs of the people and incidents of travel; but there are occasional allusions to the rocks. When crossing the Bokaro field, Jacquemont recognised the resemblance of the sandstones to the coal measures of the Raniganj field. He makes some remarks on the fossil plants.

Rev. J. Everest, 1831.

The next published paper in which allusion is made to the Geology of Mánbhúm is by the Rev. J. Everest, and is entitled "Geological observations made on a journey

[1] Vols. III and V.

from Calcutta to Ghazipúr."[1] In this paper attention is directed to the fact that at about the fiftieth milestone from Calcutta, a distinct change in the character of the alluvium is observable as there first a gravelly and lateritic soil is met with. The appearance of the rocks near Bánkúrá is described. Mr. Everest believes the Kunkur to be the product of petrifying springs. His remarks on the Damuda coal-fields have already been quoted in the memoir on the Raniganj coal-field. In reference to the possible extension of coal-bearing strata towards the south, the author says: "We know that to the south-east it does not extend to Bancurah (Bankúra), but 25 miles to the south of this latter place at Aminugar, a stone is worked similar to that in the Adjai." The similarity, however, does not exist except in the colour, as the Adjai stone is an argillaceous sandstone (Talchir) and the Aminugar (Ahmednagar or Ambekanuggar of the maps) is a chloritic schist or potstone. Mr. Everest concluded from its appearance, as seen from a distance, that Pachet hill was composed of trap from which he thinks it probable that dykes may penetrate into the adjoining country. Pachet hill is now known to be formed of sedimentary rocks only. He appears to have been much struck by the greenstone-like aspect of some of the hornblendic slates or schists and the sandstone-like structure of some of the gneiss.

J. Homfray, Esq.,[2] 1842.

In a description of the Damuda coal-fields, Mr. J. Homfray alludes to some of the characters of the surrounding rocks. He adopts the same idea as that above mentioned in reference to Panchet.

Dr. J. Row, [3] 1844.

In a paper by Dr. J. Row, entitled "Geological remarks during the march from Benares (old road) *viâ* Hazaribagh, Bánkúrá, and Bardwán to Barrackpore," the appearance of the gneiss rocks in the vicinity of the road between Chass and Bánkúra is briefly described.

The final entry in Dr. Voysey's Journal of the tour which terminated

[1] Gleanings in Science, Vol. III, p. 129.
Jour., As. Soc., Bengal, Vol. XI, 1842, p. 723.
[3] Jour., As. Soc., Bengal, Vol. XIII, 1844, p. 862.

with his death, refers to the Geology of Mánbhúm. The last words of the Journal are: "Rocks of Coliapal (Kúliápál). The same mica schist[2] with quartz veins. One specimen of quartz reminded me of axinite." After writing this he caught fever, to which he succumbed, and was found dead in his palki on its arrival at Howrah.

Dr. Voysey,[1] 1823.

Mr. Williams describes the lithological characters of the metamorphic rocks (or as he calls them the inferior stratified rocks) on the south of the coal-field, down to the neighbourhood of Bánkúrá and the Dálkisar, and on the north up to Dubrajpúr aud Súri. Strange to say, he includes in this series the rocks forming Beharinath and Panchet, which really belong to the youngest group in the area, being of much more recent origin than the coal measures.

Williams, Esq., 1847.

In a paper in the Journal of the Asiatic Society of Bengal by Mr. Piddington, a siliceo-iron-and-manganese rock from the district of Bardwán is described, for which the name Calderite is proposed. On weathered surfaces it resembles a common massive ore of iron; its appearance on the fresh fracture is exactly that of black resin; streak ash-coloured.

H. Piddington, Esq.,[3] 1850.

Analysis of a fair average.		Per cent.
Silex	46·35	
Alumina	0·35	
Lime	1·00	If of manganese and iron only.
Arsenic	0·20	
Perox. iron	30·18	58·64
Protox. manganese	21·00	41·36
	99·08	100·00
Loss, partly fluorine, of which there are traces ...	·92	
	100·00	

[1] Jour., As. Soc., Bengal, Vol. XIII, 1844, p. 862.

[2] The notes which precede this refer to Singhbhúm, and will be referred to on a subsequent page.

[3] Jour., As. Soc., Bengal, Vol. XIX, 1850, p. 145.

Mr. Piddington calls it a rock rather than a mineral, in consequence of its constituents being distinct and therefore mere aggregates.

Colonel J. C. Haughton,[1] 1854.

Colonel Haughton, in a paper on the "Geological structure and mineral resources of Singhbhúm," describes rocks which are a continuation of those occurring in Mánbhúm. His description, as well as his map as already stated, is not limited to Singhbhúm proper, but embraces a considerable area in the neighbouring districts.

Colonel Haughton was the first to detect the existence of two subdivisions of the metamorphic rocks. It will be seen by comparison of the maps that the present one does not confirm the position of the boundaries roughly drawn by Colonel Haughton. Further notice of this paper will be found in the account of Singhbhúm.

H. Piddington, Esq.,[2] 1855.

In a "Memorandum on the Kunkurs of Bardwán, as a flux for smelting the iron ores, &c.," Mr. Piddington gives the result of a series of analyses which show that the percentage of carbonate of lime in the kunkur ranges between 50 and 72. In Sylhet lime it is 96·5 per cent. A table by Mr. Taylor, of Shergarh, giving the results of his smelting experiments, is appended.

H. Piddington, Esq.,[3] 1855.

Mr. Piddington describes the Bardwán (Susunia) paving stone as a most valuable addition to our Indian building materials: he says that mineralogically it is a pegmatite. I think that the term, as now understood, is scarcely fairly applicable to it, and would rather suggest the name felspathic quartzite, or granulit.

A comparison with Chunar stone to ascertain the relative absorbent powers gave the following results, both stones having been simply exposed to the damp air of the museum :—

[1] Jour., As. Soc., Bengal, Vol. XXIII, 1854, p. 103.

[2] Jour., As. Soc., Bengal, Vol. XXIV, 1855, p. 212.

[3] Proc., A. S. B., Vol. XXIV, 1855, p. 704.

	Chunar stone.	Burdwán stone.
	Grs.	Grs.
Natural weight	2,204	1,569
When dried	2,198	1,568
Loss ...	6	1

Mr. Piddington, without making allowance for the difference in original weights, and with no reference to the specific gravities, by an evident oversight, arrives at the result that 6 : 1 represents the comparative absorbing powers of the two stones, whereas for equal weights it should be 4·2 : 1. In a second experiment both specimens were steeped in rain water for 48 hours, externally dried, and weighed. It was found that—

Chunar stone 2,204 grs. absorbed 34½ grs. = 1·561 per cent.
Burdwán „ 1,569 „ „ 6 „ = 0·382 „ „

Mr. Piddington concludes: "Hence, if we call the results of the first experiment the chemical absorption, it is as 6 to 1 in favour of the Burdwán stone, and if we call the second experiment the mechanical absorption, this is about the same, being as 0·382 to 1·561 (= 1: 4·09), or as 4 to 1, in favour of the Burdwán stone." The above correction, however, shows that the relative proportion of absorption is practically identical in both cases. The term chemical absorption is hardly applicable to the first case.

Publications by the Geological Survey of India referring to Mánbhúm.

I.—"On the geological structure and physical features of the districts of Bankura, Midnapúr, and Orissa." Memoirs of the Geological Survey of India, Vol. I, part 7.

Blanford, W. T., 1861. II.—"On the geological structure and relations of the Raniganj coal-field," *l. c.*, Vol. III, part 1.

Hughes, T. W. H., 1865. III.—"On the Jherria (Jharia) coal-field," *l. c.*, Vol. V, part 3.

IV.—"On the occurrence of gold in the district of Mánbhúm and Singhbhúm." Records of the Geological Survey of India, Vol. II, p. 11.

Ball, V, 1869.

V.—"On the occurrence of argentiferous galena and copper in the district of Mánbhúm, south-west frontier of Bengal," *l. c.*, Vol. III, p. 74.

The same, 1870.

Besides these there are several other papers having reference to the coal, iron, and limestone of the Raniganj coal-field and its vicinity.

Geological examination.

The geological examination of the metamorphic rocks of Mánbhúm was carried out from time to time, as the maps of the Revenue Survey became available, between the years 1862 and 1868. The northern portion was examined by the late Mr. W. L. Willson; the neighbourhood of the Jharia coal-field by Mr. Fedden, and the remainder by the late Mr. Ormsby and myself.

CHAPTER II.

PHYSICAL FEATURES OF MÁNBHÚM.

Section 1.—General Structure—Hills.

Westwards from Calcutta, at a distance of 120 miles, lies the district of Mánbhúm, close to the eastern frontier of which, the headlands, as they may be called, of the rocky and elevated country of Western Bengal make their first appearance. Strictly some of these headlands occur within the districts of Bankura and Midnapúr, as has already been stated in an account of the Geology of those districts;[1] but speaking generally, the geological and topographical boundaries nearly coincide, and these headlands are lapped round by the Gangetic alluvium which spreads over lower Bengal.

Boundaries.

[1] Mem., Geol. Surv. of India, Vol. I.

Area. The total area of Mánbhúm, as determined by the Revenue Survey, is 5,551 square miles.

In its western and southern portions it is very hilly, and continuously so for many miles; but to the east and north-east, the hills are for the most part quite isolated from one another and rise abruptly from the plains. The highest hill in the district is Dulma 3,050′ or (1,430′ lower than Parisnath). The other principal hills are Tundi, Panchet, Beharinath, Susinia, 1,440′, Gurgubúrú, 2,220′, Raghunathpúr, Tilbani, 1,336, besides many others towards the west and south.

Hills.

Dulma.

In the neighbourhood of Bhagmúndi there is a plateau with an elevation of from 1,200 to 1,400 feet above the sea, which occupies an area of about 90 square miles.

Bhagmúndi plateau.

On the south Mánbhúm is separated from Singhbhúm by a formidable natural boundary formed of several ranges of hills which are traversed by a few gorges.

South boundary ranges.

Section 2.—Rivers and Rain Basins.

The drainage of Mánbhúm is effected by four principal rivers with their tributaries, and the area is consequently divisible into as many rain basins. These rivers are the Dámúdá, Dálkisar, Kosái, and Subarnarekhá, all of which pursue independent courses till they fall either into the Húgli or the sea. The Dámúdá rises in Házáribágh, the Kosái, and Dálkisar, within the limits of Mánbhúm, and the Subárnárekha in Lohardaga close to the station of Ranchi. All these rivers during the rains, and, occasionally at other times, carry down immense quantities of water, impeding local traffic and sometimes causing destructive floods in the plains. In the dry weather the streams are so much reduced, occasionally even disappearing, that it is only barely true to speak of them as being perennial.

Principal rivers.

Sources.

Floods.

Various projects for storing the flood waters of these rivers have from time to time been promulgated and surveys have been made, but as yet no further steps have been taken.

Projects for storing the water.

The valley of the Dámúdá is chiefly remarkable for containing in succession, from east to west, the detached coal-fields of Ranigánj, Jhariá, Bokáro, Rámgarh, and north and south Kárápúra.

Valley of the Dámúdá.

From the neighbourhood of the Jhariá coal-field rafts of timber used to be floated down the river during the rains. And from Raniganj, coal, formerly in considerable quantities and still to some extent, is despatched to the Húgli by the same means.

Dámúdá used as a means of carriage.

In Mánbhúm the principal tributary of the Dámúdá is the Barákar, a river particularly subject to sudden floods. The Grand Trunk Road crosses it by a handsome bridge.

Barákar river.

The Adjai bounds Mánbhúm on the north-east, but its junction with the Dámúdá is outside the limits of the district.

Adjai.

The Dálkisar passes out of Mánbhúm close to the civil station of Bankúra; its course to that point runs for from 35 to 40 miles. As a general rule, it affords indifferent sections of the underlying rocks, the reaches being, for the most part, filled with sand and clay.

Dálkisar.

The Kosái, on the other hand, gives, especially in the higher rocks, some very fine sections of the slates, quartzites, &c. Its course in Mánbhúm strikes across the district from north-west to south-east for upwards of 100 miles.

Kosái.

In Midnapúr it runs south of the civil station, and has there attained considerably increased dimensions, and is crossed by a weir or anicut in connection with the Cuttack Canal.

The Subarnarekhá crosses the south-west corner of Mánbhúm, cutting off the pargana of Pátkúm. This river has long been justly renowned for the great beauty of

Subarnarekhá.

its scenery. On the borders of Házáribágh it forms a cascade called Húndrú Gág, which is said to be 320 feet high. In the lower parts of Mánbhúm, especially where it traverses the sub-metamorphic rocks, it abounds in bold and striking views, many of which illustrate, in a very beautiful manner, the effects of river denudation, as we shall have to notice again further on. Its name, *Subarnarekhá*, or Golden-streaked, is derived from the fact of gold being found in its bed.

Section 3.—Denudation.

The phenomena of denudation observable in Mánbhúm, though by no means on a magnificent scale, are of an interesting character, and sufficiently considerable to afford evidence of their having been produced by causes which must have been in operation for long periods of time. All these phenomena are referable to one class of denudation, that known as subærial, the active agents of which are rain and rivers.

Subærial denudation.

The oft-repeated ideas, that the present boundary of the rocks on the east of the peninsula from the Chilka lake to the Rájmahal hills corresponds with an ancient coast line, or that the hills and plateaus in comparatively recent times occupied the position of islands in a sea,[1] have not received confirmation by a single observation on denudation made during the systematic examination by the Geological Survey.

No trace of marine denudation.

Although the older rocks exhibit abundant evidence of having been subject to considerable crushing, faulting, and disturbance, still, in so far as the present contour of the country is concerned, the result of all that action might have been to have left the surface a plain.

Original disturbance of the rocks.

The outlying hills and prolongations of the Chutia Nagpúr plateau owe their origin and character to denudation modified only by the inclination of the beds, and not to local or special upheavals. That the general level of Mánbhúm corresponded to that of Chutia Nagpúr in times previous to the scoop-

Hills and spurs produced by denudation.

[1] Everest: Gleanings in Science, 1831, p. 133.

ing out of the Damúdá and other valleys, and the deposition of the coal-measure and associated rocks, is proved, not only by the scattered hills, a few of which approach in elevation that of the Chutia Nagpúr plateau, but by the fact that the Subarnarekhá and many of its small tributaries pass at right angles through gorges cut deep through hard ranges of trap, quartzite, and tough mica schists.

Gorges.

It is perfectly clear that these gorges must have been formed by gradual cutting down *from above*. It is inconceivable that, supposing the ranges to have been originally locally elevated above the surrounding country, the rivers could by any means have penetrated them. In fact, they must, in that case, have formed everlasting watersheds.

Ranges how formed.

The *modus operandi* seems to have been that the Subárnárekha and some of its tributaries crossing the high ground gradually cut their way down *across* the strike of the hard rocks, while the remaining tributaries acted *along* the strike, scooping out the softer rocks and leaving the hard ranges in relief. In this way alone can the peculiar gorges which traverse the ranges separating Mánbhúm from Singhbhúm be accounted for.

Limits of sedimentary rocks.

The southern boundaries of the Raniganj and Jharia coal-fields being formed by faults are facts affording presumptive evidence that the sedimentary rocks extended for some distance beyond their present limits. But since throughout the varied country which stretches for 100 miles to the south, no trace of these rocks has been met with, it is probable that they were confined to the southern limits of the Damúdá valley.

Possible extension northwards.

It would be difficult to believe that denudation had removed all traces of these rocks, supposing them to have existed, from valleys in all probability as old as that of the Dámúdá. On the north of the coal-fields the case is different, and the outlying patches of Talchir and Dámúdá rocks in Birbhúm may be remnants of a once continuous spread of the sedimentary rocks in those directions.

Section 4.—Hot Springs.

In the neighbourhood of the Damúdá there are three hot springs, one on the faulted boundary of the coal-field below Chanch. There is or was a small bath erected close by to collect the waters for the benefit of visitors from Barákar. The second is on the south bank of the Damúdá near the village of Tantulia. It is said to have a temperature of 190° F.,[1] and is decidedly sulphurous. The third is on the north bank of the Damúdá close to the village of Sheodpúr, and near the junction of the Ghee river with the Damúdá. There is another hot or tepid spring on the south-west corner of Susunia hill.

CHAPTER III.

Section 1.—Formations represented.

The formations occurring in Mánbhúm are—

1. Alluvium.
2. Laterite.
3. Mahadeva (Upper Panchet).
4. Panchet.
5. Damuda.
   - *a.* Raniganj group.
   - *b.* Ironstone „
   - *c.* Barákar „
6. Talchir „
7. Sub-metamorphic.
8. Metamorphic.

In this account our remarks will be confined to Nos. 1, 2, 7, and 8.

Coal-fields previously described.

In the Memoirs on the Raniganj[2] and Jharia[3] coal-fields, Nos. 3, 4, 5, and 6, in so far as they occur in the Mánbhúm area, have been fully described.

[1] C. Betts, Esq.: Jour., As. Soc., Bengal, II., 46.
[2] Mem., Geol. Surv. of India, Vol. III, pt. 1.
[3] Mem., Geol. Surv. of India, Vol. V.

Section 2.—Superficial Deposits.

ALLUVIUM.

Considerable areas within the eastern rock boundary are covered by alluvium, but Mánbhúm is not a favourable district for studying the character and sub-divisions into which, according to the examination of other more eastern districts, the alluvium of Bengal is divisible. At many places in Mánbhúm there are thick deposits of clay, the most important of which is at the northern base of the Bhagmundi plateau, where it sometimes attains a thickness of 60 feet, and often includes, at its base, a vast accumulation of rock detritus from the adjoining hills.

LATERITE.

Laterite occurs pretty generally distributed over the district. Along the eastern boundary, and especially in the Raniganj field, there is a deposit of several feet in thickness. Four distinct varieties of this rock occur, which may be thus described—

1. Pisolitic, sometimes concreted, but towards the surface generally in the form of loose gravel.
2. *a.* Conglomeratic—contains both rounded and angular fragments of quartz.
   b. Conglomerate passing into coarse grit.
3. Concretionary.
4. Compact occurs in stratified beds.

3 and 4 seldom occur inside the boundary, *i.e.*, resting directly on the metamorphic rocks, but are associated with beds of alluvium outside.

CHAPTER IV.

SUB-METAMORPHIC OR TRANSITION SERIES.

Section 1.—Area, &c.

Origin of term sub-metamorphic.

The term *sub*-metamorphic has been adopted by the Geological Survey of India as a convenient name for a series of rocks which, while, as a general rule, showing distinct signs of metamorphism, do so in a much less degree than do the

gneissose or metamorphic rocks proper. The prefix *sub* refers then to the amount of metamorphism, not, as might be supposed, to the position in the geological scale.

Other names.

In different parts of India, where rocks of this character occur, various local names have been adopted: it yet remains to be seen how far they can be safely correlated with one another, and with similar series of other countries.

Correspond to Huronian and Cambrian.

Speaking generally, however, the sub-metamorphics of Bengal may be said to occupy a position in the geological scale roughly corresponding to that of the Huronian of Canada or the Cambrian of Europe.

Principal area.

In Mánbhúm the principal area occupied by the sub-metamorphic rocks is situated in the southern half of the district. On the north it is bounded by a fault which is distinctly marked, and has been traced from the borders of the alluvium near Belaidiha westwards to a point beyond Bandgaon in Lohardaga, or for a distance of rather more than 100 miles. Southwards from Mánbhúm the area extends into Singhbhúm, where the sub-metamorphic rocks

Extension in Singhbhúm.

surround or cloak an area of metamorphic rocks, the boundary being for the most part natural.

Extension westwards.

In their western extension these rocks have been traced continuously as far as Raiboga in Gangpúr, so that it is only a small portion of the whole area occupied by the series in Chutia Nagpúr which is included in the district of Mánbhúm.

Detached areas.

Besides being found in this main area the sub-metamorphic rocks exist also in smaller outlying tracts resting on the older metamorphic rocks. The principal of these are situated near Súpúr and Manbazaar, where the rocks are much cut up by faults, to the local subsidences in connection with which their preservation is probably due. At more distant localities there also occur rocks which lithologically resemble some of the principal forms of the sub-metamorphics, but some of these exist as bands in the older rocks, and are quite inseparable from them.

Section 2.—Lithology.

So far as the rocks of this series have been examined, they appear to be azoic. They consist of quartzites, quartzitic sandstones, slates of various kinds, shales, hornblendic, mica, talcose and chloritic schists, the latter passing into potstones, and interstratified greenstones or diorites with? trappean ashes. In adjoining areas limestones and calcareous schists, containing actinolite, tremolite or other adventitious minerals, occur also in this series, but have not yet been met with in Mánbhúm.

Limestones occur in adjoining areas.

The presence of beautifully preserved ripple-marks in the slates and shales shows that the metamorphism has not been of a very complete or uniform character. Were it not for the quartz veins, which traverse them, some of the green shales are so little affected by metamorphism that they might be mistaken for Talchirs.

Ripple-marks.

That the rocks composing this series may ultimately prove susceptible of sub-division into groups is possible, but a considerable amount of time would be required for tracing out individual beds before any such separation could be made, since, owing to the inequality and irregularity of the metamorphism, mere lithological characters afford an insufficient test for comparison.

Possible sub-division.

In negative characters the absence in the series of any rocks, whether as beds, veins, or intrusive dykes, to which the term granitic can be applied, is the principal.

Negative characters.

Foliation, or the homogeneous arrangement of the component minerals in any way, does not occur in these rocks save in some of the schists.

As compared with the rocks of the metamorphic series, these are rich in ores and metals, the following having been found in Mánbhúm: gold, copper, argentiferous galena, and iron.

Rich in metals and ores.

As has already been stated, the physical features characterising the areas occupied by the sub-metamorphic rocks are very different from those prevailing in the meta-

Physical features.

morphic tracts. In the former, the harder varieties of rocks form ranges of hills which strike with the bedding, and in most instances the beds persist with the same thicknesses and relative position to those on either side of them, for very considerable distances.

Hill-formers.

The succession of the hill-formers is best seen in the neighbourhood of the Subarnarekhá, where the peculiar characteristics of each is well represented. Most northern is a cherty quartzite which rises into saddle-shaped hummocks, then follow two chains of truncated or perfectly conical hills formed of slate, then a massive range of irregular elevation, composed of intrusive trap, whose highest part forms the fine hill called Dulma.

South of it there are two ranges, one of granulit or felspathic quartzite, and the other of talcose and micaceous schists of tolerably equable elevations throughout. As mentioned above, they are traversed at intervals by gorges which have been produced by river cutting operating from above.

Before proceeding to the detailed description of this area, it will be well to discuss two subjects which are intimately connected with its physical features. These are the faulted character of the northern boundary and the intrusive origin of the great trap dyke which, as just alluded to, forms Dulma hill.

Section 3.—Faults and Dykes.

Pseudmorphic uartz.

In the alluvium on the East, close to Belaidiha, the position of the boundary is indicated by a ridge of pseudomorphic quartz, which, as we shall presently show, accompanies it at intervals for many miles. A little further west, off the alluvium, where the rocks are reached, there is abundant evidence of disturbance, and the rocks on either side dip away from the line of fracture. This line of fracture, as not uncommonly occurs, soon shows itself to have become, by means of infiltration, the receptacle of various ores,

Etched surface of quartz.

but principally of those of iron. In many places iron has been replaced by quartz, some of the

pseudomorphic plates of which show the delicate etching which occurs on specular or micaceous iron, while in other cases the iron has not been completely removed, but is retained in the interstices.[1] Occasionally the quartz pseudomorps are after gypsum or barytes. Sometimes the quartz occurs massive, but penetrated by numerous intersecting veins.

Hæmatite along fault.

Near the village of Barabun, further to the west, there is a run of this fault rock, and at the Pora hill both fault rock and brown hæmatite occur. Close by, the fault cuts off a small area of sub-metamorphic rocks from the main tract and north and north-east of Ambikanagar, the line of crush is again marked by lodes of hæmatite, which appear to contain a great abundance of rich ore. From this for 6 miles further west, save in the contrast of the rocks on either side, there is no surface evidence of the exact line of the fault. But in the hills between Bulrampúr and Bauch there is another strong deposit of hæmatite, beyond which and on the same disturbed line there is an old worked out copper-mine in which traces of malachite and azurite are still to be found as encrustations on the neighbouring rocks. In its vicinity there is a vein of coarse crystalline dolomitic limestone.

Copper mine.

Limestone.

Hæmatite is marked *coal* on map.

A little further west there is another large outcrop of hæmatite which was erroneously marked *coal*, on the original Revenue Survey map. After this the fault again cuts off a narrow strip of sub-metamorphic rocks from the main area. Its position from hence westwards is marked by a range of hills 250 to 300 feet high, which are formed of pseudomorphic quartz of similar character to that above described. They strike to 25° north of west, and continue for a distance of about 10 miles. North of Barábazar, a branch fault coming from due east joins the main one, which then pursues a slightly north of west course, and can be easily traced by exposures of fault rock and faulted junctions for a distance of 18 miles. South of Dabah

[1] I have in a previous paper discussed this subject more fully. *Vide* Mem., Geol. Surv. of India, Vol. VI, p. 129.

there is a range of hills similar to those just mentioned, and formed exclusively of the pseudomorphic quartz. These hills are particularly interesting, as affording a minimum index of the thickness of rocks removed by denudation subsequent to the faulting. West from Dabah the position is marked by veins of brown hæmatite. Close to Jánúm a cross fault has flung the main fault somewhat out of direction, beyond which a low ridge of pseudomorphic quartz marks its position up to the Subárnárekha, in the section in which river its effects are apparent.

Range of hills marking position of fault.

Cross fault.

Western extension of main fault.

West of the Subárnarekha and Patkum it has been traced for many miles beyond our area into the Lohardaga district.

The Dalmá Trap.—Traversing the sub-metamorphic rocks from east to west there is a run of trap of very unequal dimensions, as it varies in width from about $\frac{1}{8}$th of a mile up to nearly 3 miles. Sometimes it bifurcates, its branches having broken through the bedding of the surrounding rocks.

Three alternatives present themselves to account for its origin, *i.e.*, it is either *1st*, cotemporaneous, *2nd*, a superficial flow, or *3rd*, intrusive.

Origin.

1st.—Its branching irregular dimensions, and in places the obliquity of its direction to the general strike of the bedding, may be taken as conclusive evidence of its non-contemporaneous origin.

2nd.—That it is not capping trap is apparent from the fact that it occurs at the lowest part of the river sections, especially in the Subárnárekha, where it has evidently crushed up through the beds, and because, at no part of its course, from the Midnapúr District to Lohardaga, does it, in section, appear to rest on any other rock.

3rd.—Its great dimensions and the complex character of its component parts at first make one hesitate to regard it all as an intrusive dyke, still there is no reason why a dyke should not present these peculiarities, uncommon as it may be for them to occur. In reference to the surround-

ing rocks this trap occurs in a trough, the beds on either side dipping towards it; but since there is no repetition—the beds on the immediate north being slates and quartzites and those on the south schists and granulit—it is clear that at the base of the synclinal trough there must be a dislocation of the strata, and it would appear that it was along this line that the molten matter was thrust up. Other independent evidence of a crush up occurring here is furnished by the existence of lodes of hæmatite along the northern edge of the trap, which are precisely similar to those occurring on the great fault. Tracing this dyke from east to west, it presents the following appearances :—

Synclinal.

South of Dhadka, near Rajgaon, it is very much broken up, as it also is in Midnapúr. About 2 miles west of Dhadka it commences a steady course, which continues unbroken up to the Subárnárekha, and is thence continued many miles into Lohardaga. South of Dusra there is a bend in the direction of the dyke which is not shared in by the surrounding rocks, as they preserve a steady strike.

Course of the trap.

North of Asanbuni the southern flank of Dulma is, for the most part, obscured by a talus of trap boulders. Ascending the hill the same trap is seen *in situ* until the first ledge is reached, there in the bed of a stream, there is an indurated chloritic rock exposed. At various points throughout the dyke, bands or included masses of this rock occur. Several opinions as to their origin might be offered :

Section.

1st.—They are portions of the trap itself, characterised by the segregation of chloritic minerals or their local production by alteration.

2nd.—They are detached masses of original rock carried up from below.

Origin of chloritic enclosures.

3rd.—They are schists *in situ*, which are merely enveloped by the intruding trap.

The first might possibly be the true explanation, as such cases are not unknown; at the same time the rock closely resembles in lithological character some of those which occur interbedded in the sub-metamorphic

series, so it is more probable that the 2nd or 3rd alternatives, or both, afford the true explanations.

Above this there is trap again until the summit is reached. The trap of the summit and main axis of the hill is a decided *breccia*, while that of the lower portions is compact or amygdaloidal.

Section north of Ramgarh.

The section across the dyke north of Ramgarh is somewhat different from that just given—It is

1. Indurated chloritic schist.
2. Porphyritic trap.
3. Indurated chloritic schist.
4. Compact and amygdaloidal traps.
5. Indurated chloritic schist.
6. Brecciated trap.
7. Indurated chloritic schist.
8. Brecciated trap.

Breccia.

The brecciated trap is well seen in the bed of the Subárnarekha north of Kutia. It is possible that the brecciated appearance may be due to segregation; but it is more probable that the contained masses are fragments of an original outburst, which have been taken up again and partially reconsolidated by a more recent one.

Interbedded traps.

Hornblendic rocks occur in the formation, which, if they are of igneous origin, were probably contemporaneous; but being interbedded, a doubt must always exist as to their true character.

Supposed burning mountains.

Dulma and some other hills, in both Mánbhúm and Singhbhúm, have long been accredited, according to native report,[1] as being burning mountains: this seems to me to be traceable to the use of the word *dhuan*, which is as often used for steam or vapour as it is for smoke. Such *dhuan* I frequently saw rising from these hills after rainy weather, when the morning sun produced wreaths of vapour singularly resembling smoke.

[1] *Vide* Colonel Haughton's paper, Jour., As. Soc., Bengal, Vol. XXIII.

Section 4.—Detailed description.

Sub-metamorphics of the main area from Belaidiha and Raipúr to Patkúm.

In the bed of the Kosai, west of Belaidiha, and close to the village of Giturpahari, within the sub-metamorphic area, there are some gneissose and schistose rocks very unlike the typical rocks of the formation. In Singhbhúm I met with somewhat similar abnormal beds. The explanation of the more crystalline character may be, that, in these localities, the process of metamorphism was locally intensified from some unknown cause.

Abnormal rocks.

The south boundary of the sub-metamorphic area crosses the Kosai river near a village called Gúriádá, whence it stretches westwards to Kuliapal, round which it bends to south. This boundary passes through dense jungle, and was traced with great difficulty.

South boundary.

South-west of Shamsunderpúr and Phúlkusma there is a considerable outlier of the younger rocks which is separated from the main mass by a zone of rocks of somewhat indefinite character. So far as seen, they consist chiefly of vein quartz with a few outcrops of schists. Towards Raipúr on the east, and Kuliapal on the west, however, they are associated with granitic rocks, so that little doubt can exist as to their true affinities.

Outlier.

This outlier occupies an area of about 16 square miles. On the south it is continued for a short distance into Midnapúr. A good section of the rocks is exposed in the river north of Phúlkusma. Close to the village of Mutguda there are some pits in the potstones, and plates are manufactured from them to a small extent.

Outlier.

From the sections in this neighbourhood, it would appear, since the boundaries are natural, that the chloritic schists and potstones, with the associated hornblendic trap-like rocks and quartzites, are the lowest rocks of the sub-metamorphics, and the Subárnárekha section, which will presently be described, confirms this view.

Potstones.

North of Dhadka there is a very marked change in the strike of the rocks, as from more or less east to west, it becomes nearly north and south. West of the same place the Gurum river gives a section of slates, schists, and earthy shales, the latter somewhat resembling those of the Talchir series. These rocks correspond to the highest in the Subárnárekha section north of Dulma.

Change in strike.

Near the house called Jani-jour, which is about 1½ miles north-east of Dekia, there is a lode of argentiferous galena in a sandy mica schist. This has been already described in a special paper,[1] and reference will again be made to it in the economic Chapter.

Galena.

Between Dekia and Rajgaon[2] there is a succession of schists and slates which is only interrupted by the occurrence of a few bands of quartzite: the dip is high to south-west. East of Rajgaon are some cleaved slates, which, however, split readily along the plains of lamination. Here, too, there are some Talchir-like shales; they are, however, interstratified with the slates and there is therefore no doubt as to their age.

Talchir-like shales.

In the Narsinghpúr Ghât, which is traversed by the Gurum river, there is a very clear section of the rocks which form the ranges of hills separating Mánbhúm from Singhbhúm. A succession of gorges, generally from 1½ to 2 miles distant from one another, enable the same beds to be traced for about 60 miles. The principal varieties are —

Section in Narsingpúr Ghât.

Slates.
Felspathic quartzites or granulit.
Talcose and micaceous schists.

Towards the north boundary the best sections of the rocks are exposed in the Kosai near Gopalpúr and Ambika-nagar, where they consist chiefly of talcose schists, potstones, hornblendic schists, and bluish quartzites.

Sections in Kosai.

[1] See Rec., Geol. Surv. of India, No. 3, part 3, 1870, pp. 74-75.

[2] Since this neighbourhood was visited, copper ores are reported to have been found near Rajgaon.

Trap-like rock.

At Bangorda, in Barabhúm, there is a trap-like rock which forms a range of bare red hills. The colour is due to the weathering out and decomposition of magnetic iron and the detritus from it is almost identical with one common variety of laterite.

Inlier of granitic rocks.

The town of Barábazar is situated on an inlier of granitic rocks south of the fault. It has somewhat the aspect of having been elevated, the slates and shales dipping from it on all sides, but this appearance may be due to sliding down of the sub-metamorphics at the time of the general subsidence.

Cleaved slates.

In the stream west of Bhora-bone hill (altitude 1,546 feet) there is a section of some slates which at first sight look like roofing slates, but are unfitted for practical use as those mentioned above, on account of their being fissile along the planes of lamination, as well as along those of cleavage. On the Chorobúrú hill north of Jhirka, there is a lode of brown hæmatite connected with a line of fault. Near Jhonjka, the continuation of the same lode is worked by the natives.

Hæmatite.

Ash.

Some of the beds seen here apparently contain a considerable proportion of volcanic ash, as a constituent. The origin of this ash, which occurs at many other places also, may be connected with that of some of the interstratified hornblendic rocks, which are possibly cotemporaneous trap; but there can of course be no connection with it and the Dulma (intrusive) trap.

Slates hardened.

The slates in the neighbouring hills to the west have been much hardened in consequence of their proximity to the Dulma trap. They break with conchoidal fracture and give out a metallic sound on being struck. Some of them, in hand specimens, might be mistaken for one of the compact varieties of basalt.

Section near Chondil.

In the ghât north of Chondil there are blackish slates, shales, and quartzites; they may all be traced for several miles beyond the Mánbhúm boundary into Chutia Nag-

Dip south 30°.

57. Hornblendic (Trap?).
58. Potstone.
59. Hornblendic.
60. Potstone.
61. Shales.
62. Blue quartzite and phyllite.
63. Green and mottled grey shales.
64. Quartzite with veins of quartz.
65. Shales.

Fault.

Granitic gneissose rocks and schists.

The above, it must be remembered, is a section of the rocks seen in the Subárnárekha, and is not intended to be taken as a complete section of the rocks of the formation. Up to No. 27 the general dip is northwards, and from that it is southwards, although no distinct repetition can be made out on either side of the trap and its accompanying fault.

Cross faults.

Outlying areas of sub-metamorphic rocks.—North of the main fault, in the vicinity of Súpúr and Manbazaar, there are a few outlying areas of sub-metamorphic rocks which appear to owe their preservation principally to a series of cross faults which have let them down into the older rocks. These faults are all well marked, the edges of the different formations being in some places in abrupt contact and in others only separated by ridges of pseudomorphic quartz or lodes of brown hæmatite. The rocks occurring in these areas are chiefly alternations of quartzites, potstones, and hornblendics corresponding to the lowest part of the section given above. It would be tedious and unnecessary to repeat all the field-note-book details of these areas. All the information likely to be required concerning them is contained in the original field maps on the scale of 1 inch = 1 mile. As in the main area, the superficial deposits are in these also more or less auriferous.

Auriferous deposits.

Doubtful sub-metamorphics.

In the northern parts of Mánbhúm, there are, in several places, rocks which bear resemblance to the sub-metamorphics, but which possibly only exist as bands in the

older rocks. Of such cases the least doubtful is that of the rock forming Sasunia hill, well known in the district as the locality in which the so-called *Bardwán* paving stone is obtained.

Sasunia Hill.

Sasunia hill is about 17 miles south-south-west of Raniganj; it rises abruptly to a height of 1,443 feet. It is chiefly formed of quartzites and felspathic quartzites or granulit, with occasional traces of mica. The general dip of the beds is 20°—25° to 10° east of north, but owing to some rolls and contortions, the direction varies from this to east-north-east and north-east. The beds are traversed by three systems of joint planes which facilitate the quarrying of the stone to a very material extent.

These systems strike—

North and south, dip 30° west.
5-10° west of north, 5-10° east of south.
10° north of east, 10° south of west.

A rough calculation makes the thicknesses of these beds to be about 360 feet.[1] I was unable to trace them in the section either on the east or west, and I am therefore inclined to believe that they are unconformable to the gneiss series, and exist as an outlier from the sub-metamorphics series, to the rocks of a zone in which they present a lithological resemblance.

Thickness.

North of Jaipúr, in the Gardia hill station and its neighbourhood, there are some quartzites very like the sub-metamorphics, but which appear to be interbedded with gneiss, such as never occurs in the sub-metamorphics. The continuation of these rocks in the Lohardaga District was noted by the late Mr. Ormsby, who describes them as being very like the sub-metamorphics, but he did not attempt to map them as separable from the metamorphics.

Gardia hill.

Continuation in the Lohardaga District.

Towards the north-west of the area and passing into Házáribágh, Mr. Willson observed some quartzites and chloritic schists intercalated

[1] In the section on economic resources, a further notice will be given of these rocks.

with the gneissose rocks. In Házáribágh, north of Barhi, there is a strip of slates and quartzites considered to be identical with the transition rocks of the Rajgir hills to the north.

CHAPTER V.

Metamorphic Series.

Section 1.—General remarks, Lithology, &c.

That portion of the crystalline rocks to which the term metamorphic is applied includes a considerable variety of different forms of gneiss and schist, &c., which constitute the fundamental series of India, and so correspond in geological position to the Laurentian series of Canada and Europe.

In India the metamorphic rocks occupy enormous areas scattered over the country. The sum of these areas probably does not fall short of 250,000 square miles.

Efforts have been made from time to time to divide these rocks into groups, but hitherto without much success. The lithological characters which enable a sub-division to be made in one area are often found not to hold good in adjoining areas: gradual transitions being found to exist between rocks at first supposed to be susceptible of separation.

Lithological characters local.

It would be possible to represent on the map the area occupied by the schists, &c., as contrasted with those in which granitic rocks prevail. But such a map would be a purely lithological one and of very slight geological value as bearing on the general structure of the country.

Lithological sub-division possible.

There are good reasons for believing that, both in the metamorphic and sub-metamorphic areas, cases of excessive local metamorphism not unfrequently occur. The origin of these in a few instances may be attributable to the intrusion of

Local excess of metamorphism.

igneous rocks. In other cases the causes are not so apparent. If local excessive metamorphism does occur, it follows that lithological characters are an unreliable guide to the original structure.

Thickness.

Assuming that the layers of rock which now exist correspond to original beds—and I see no other means of accounting for the constant alternations of character which exist in the successive gneisses, granites, schists, hornblendics, and quartzites—then the total thickness of rocks must be enormous. Any estimate of its amount which can be made is unsatisfactory from the difficulty of obtaining a starting point from which to measure no less than from the crushing and disturbance of the beds.

No datum for measuring the amount.

Section in Tusurkow and Gowhail.

A section in the Tusurkow and Gowhaie rivers which I measured gave a thickness of upwards of 5 miles. Although no distinct repetition was observed, still such may have existed, being unrecognisable owing to local differences in lithological characters.

Original boundaries obliterated.

If, as is probable, this immense thickness of crystalline rocks represents several original formations or series of sedimentary rocks, it would appear that their original boundaries have become obliterated and destroyed by the crushing up and metamorphism. Certainly no boundaries other than those which are simply lithological have been yet detected.

Granitic rocks.

Another great source of difficulty in the attempt to separate these rocks and trace out their original structure arises from the presence of granitic rocks which do not show a trace of foliation, and of the igneous or metamorphic origin of which we have no crucial means of determining. It seems doubtful whether microscopic sections even would afford an infallible test. Exact lithological counterparts of these granites often exist as beds interstratified with schists, quartzites, &c., while their physical characters, when seen on the large scale, sometimes suggest an igneous origin.

Hornblendic rocks.

The same remark applies to the hornblendic rocks, which, in some places, resemble trap, often, however, passing within short distances into distinctly foliated rocks.

The principal varieties of rocks which constitute and occur, associated with, the metamorphic series in Mánbhúm are—

1. Mica schist.
2. Chloritic schist.
3. Quartzite.
4. Granulit.
5. Hornblendic ... Gneissose. Schistose. Syenitic. Trap-like (Dioritic).
6. Ordinary gneiss.
7. Granitic „
8. Porphyritic granitic gneiss.
9. Granite, unfoliated.
10. „ veins.
11. Quartz „

IGNEOUS ROCKS.

12. Trap.
13. Syenite.
14. Granite.

Section 2.—Detailed description of Country west of the Raniganj coal-field and north of the Dámúdá.

The principal rocks in this area consist of a pale brown quartzose gneiss with bands of a more granitoid variety and hornblendic rocks of different degrees of texture, if not of composition; they vary from schists, in which the component minerals occur distinctly, to a compact greenstone-like rock; mica-schists are of more rare occurrence in this part of the area, but are seen at Pandua Hât, and elsewhere. Quartzites occur at several places, as in the Jumerah range south of Fitkeri.

Porphyritic gneiss.

North of Govindpúr, and thence passing westwards south of Jammúngi, and so on north of Topchanchi towards Parisnath, there is a band of coarse porphyritic granitic

gneiss similar to one described further on, and which occurs in central Mánbhúm. On the south this rock changes into a dark green syenite containing imperfect crystals of pink felspar. On the north it is covered by pale brown and yellowish-brown gritty gneiss.

Syenite.

All these rocks are much contorted, and exhibit dips varying from 20° to the vertical: the general direction of the dip is to north, sometimes to the north-east, but occasional rolls cause it to be southerly for short distances.

This area is traversed by numerous trap dykes and veins of granite quartz, and pseudomorphic quartz or fault rock, the general direction of their strike is north-west to south-east, which is also that of some of the minor joints in the beds.

North of Pandua Hât there are some thick and thin and even-bedded grey, pale drab and brown quartzo-felspathic rocks with a dip of 10°—15° to north, which show but small signs of metamorphism.

In the north-west of the area there is a considerable group of hills known as the Túndi range, in which three different kinds of rocks impress their peculiar physical characteristics on different ranges. These are ordinary gneiss with bands of hornblendic gneiss, trap and fault rock. Gneiss of the granitoid type does not occur in the hills.

Rocks of the Túndi range.

Between Pandua Hât and the Túndi hills, Mr. Willson obtained the following section:—

LOWER PORTION...	Thin laminated hornblendic schists, with various bands of grey-brown and yellowish-brown schists and quartzo-felspathic rocks.
MIDDLE PORTION.	Thick, massive, even-bedded quartzo-felspathic gneiss rocks with micaceous schists alternating, and small bands of intercalated quartzites. The coarse porphyritic gneiss also occurs with these rocks. Hornblendic rocks are rare, but not exactly absent.
UPPER PORTION...	Mostly quartzo-felspathic, but there are many bands of grey schistose gneiss, some of which is granitoid, with irregular bands of coarse and fine hornblendic rocks.

It would be tedious and unprofitable to attempt to give more than a brief abstract in these pages of the mass of details which have been collected in this area. I shall therefore next describe the country south of the Dámúdá.

Hills south of coal-field.

South of the well marked fault which bounds the Rániganj coal-field, there are a number of hills composed of several varieties of gneiss. The principal hill-former is a very quartzitic rusty-looking variety which contains garnets; this in some places, owing to the presence of hornblende, becomes syenitic, and then commonly weathers into rounded boulders. On the Bankúra road, at a distance of about 7 miles from Rániganj, a number of ridges of a peculiar felspar porphyry are met with; their general strike is from east 35° north to west 35° south, and therefore oblique to that of the gneiss which in this neighbourhood seldom departs from true east and west.

Felspar porphyry.

West of the road these are traceable for a distance of about 7 miles, after which they die out, and on the same strike trap-like hornblendic rocks occur throughout a considerable area. The character of this felspar rock is somewhat variable; in places it contains a small quantity of diallage, which entitles it to be ranked as a Gabbro. It seems to be confined to this locality, as I have never met with a similar rock in any other part of Chutia Nagpúr. Some very picturesque tors and piles of weathered blocks occur along the line of strike at intervals. The hornblendic rocks just alluded to are of doubtful origin; in some places they seem to be greenstones or diorites, in others they pass into metamorphic schists.

Gabbro.

Hornblendic rocks.

A few miles further south is the Sasunia hill, which has been above claimed as an outlier of the sub-metamorphics. The rock forming the Kora hill, which is situated about 7 miles due east, is formed of a distinctly gneissose rock, not in the least resembling the granulit or felspathic quartzite of Sasunia.

Sasunia hill.

In the country south from this there is evidence of local disturbance, but the general east to west strike is soon recovered. Further south again the rocks are much obscured by superficial deposits of local origin and derived from the decomposition of the gneiss. Alluvium, kunkur, and laterite also abound. Such rocks as are seen are the common varieties of gneiss alternating with hornblendic schists, which are much traversed by veins or dykes of granite and quartz.

Country south of Susunia.

Close to the bridge on the Bankúra road, near the village of Duldaria, there is a boss of granitic gneiss, it rises above the superficial deposits covering the surrounding rocks. It contains both black and white mica, felspar, and quartz, with some imperfect crystals of magnetic iron scattered through the mass.

In the station of Bankúra the rocks are almost completely hidden by quartz and laterite gravels. To the south-west of the town, in the bed of the Dalkisar, near Rajgaon, there is a considerable variety of granitic and other gneiss rocks. The prevailing dip is to the south-west, but it is sometimes to south.

Bankúra.

South of the village of Borut there is a section of hornblendic and granitic rocks very closely resembling those seen in the Tusurkow river, and which will be described presently. Throughout this area dykes of greenstone and diorite, with some bosses of apparently igneous syenite, occur at intervals. The former are, some of them, continuations of dykes which traverse the Raniganj field and the country immediately to the west of it.

Section of hornblendic and granitic rocks.

Near Kaliabasia and at Magúrá there are several hills and small bosses of trap which seems to have had an eruptive origin. Were they formed merely of superficial trap, we should be justified in expecting to see the underlying rock laid bare by denudation, as we certainly are in supposing that the general level of the country has been lowered by that process: the Magúrá rock towards the top becomes coarsely crystalline, and, as it there includes free silica, must be considered to be a syenite.

Kaliabasia and Magúrá.

West of these hills there is a marked change in the character of the gneiss. The frequency of the hornblendic alternations is diminished and granitic gneiss occurs in thick beds with a marked boss-forming tendency: north from this there is a group of hills, the highest of which are Tilbani hill station and Sindarpúr. The rock forming the principal portion of these hills is one about which considerable difference of opinion might exist. Its composition is essentially syenitic, but it possesses one character which renders it doubtful whether it should be regarded as an *igneous* rock. Hornblende occurs pretty equally distributed through the mass in spindle-shaped crystals, the major axes of which have a marked parallelism throughout, which gives an aspect of metamorphic foliation to the rock. It weathers into huge masses, which are sometimes 40 feet in diameter; these, when seen piled on one another, as on the Sindarpúr hills, produce a very striking effect. The Tilbani hill is also partly formed of porphyritic gneiss similar to a rock we shall have to describe further on.

Change in character of rocks to west.

Syenitic rock of Tilbani.

Returning to the neighbourhood of the Raniganj field, the gneissose and schistose rocks which occur in the neighbourhood of Rampúr are locally characterised by containing interbedded calcareous schists. These have become of considerable importance, having been found to be the best source of lime available in the area for the manufacture of iron by the Bengal Iron Works Company. They have been described[1] by Mr. Mallet, who visited the locality since the ground was opened up and quarrying had commenced.

In the Gowhai river, which falls into the Dámúda at the eastern extremity of the Jharia coal-field, and in its tributary, the Tusurkow, there is a very considerable thickness of the schistose and distinctly bedded gneissose rocks which occur in that part of the area. These rocks contrast very strikingly with those of granitic type which prevail to the west and south-west.

Gowhai and Tusurkow section.

[1] Rec., Geol. Surv. of India, Vol. X, p. 148.

Mica schist.

The mica schist of the Gowhai section dips with its associated gneisses steadily to the north. It shows considerable variation in lithological characters, passing by gradual transitions into either gneiss or hornblendic schists. It

Composition.

consists generally of felspar and margarodite; free quartz is seldom absent. Black mica sometimes takes the place of the margarodite. Garnets, tourmaline, magnetic

Adventitious minerals.

iron and kyanite are the commonest adventitious minerals which occur in them.

Talcose schists occur occasionally with these rocks. Chloritic schists

Potstones.

passing into potstones are also found. In some instances they have been quarried for plate-making, but being generally distinctly schistose, and, therefore, too fissile, they are much less suitable for the purpose than are the compact varieties which are common in the sub-metamorphic series.

Granite and pegmatite dykes occur frequently in this section, some

Granite and pegmatite.

of them of considerable size, and they are often accompanied by disturbance, though they are probably a consequent of such disturbance rather than the cause of it.

Perhaps the most striking crystalline rock in Mánbhúm is the

Porphyritic granitic gneiss.

porphyritic granite. In an account of the metamorphic rocks of a portion of Házáribagh.[1] I have described the lithological and physical characters of this rock. But as that account is possibly not in the hands of, or readily accessible to, readers of this report, it will be better perhaps briefly to recapitulate.

It is a coarsely granitic rock composed of quartz, mica, and orthoclase

Composition.

felspar, the latter occurring both in the general matrix and in peculiar (sometimes twin) crystals, which in section form an obtuse ellipse. As a general rule, they are scattered indiscriminately in the mass and so give rise to a conglomeritic

Origin of felspar crystals.

appearance. They appear to have segregated round nuclei forcing aside the matrix, the pres-

[1] Mem., Geol. Surv. of India, Vol. VI, p. 2.

sure from which impressed upon them their amygdaloidal shape and prevented the formation of the ordinary crystals. Analyses of this rock and its contained felspar will be found on pages 43 and 44.

Physical characters.

The physical character which has drawn attention to this rock is its tendency to form rounded, dome-like, bosses and tors. The former have been supposed by some to be *Roches Moutonnées*, the result of glacial action; but examination reveals the fact that they consist of a concentric series of shells of varying thicknesses. These become gradually broken up, which operation is facilitated by an irregular cross series of joints which permit of the fragments becoming detached and sliding down the sloping sides.

Origin of structure.

These shells appear to be due to spheroidal jointing produced in the rock when cooling from the high temperature, which effected its metamorphism, supposing it not to be an igneous rock. As a rule, foliation is obscure, but sometimes it or a structure closely resembling it is very clearly seen. Domes of similar [1] character in Southern India were described by Newbold, who was perhaps the first to recognise and explain the peculiar structure.

In a special paper on this subject [2] I have drawn attention to the fact that a similar rock which occurs on the Grimsel in Switzerland presents rounded surfaces of precisely the same character and origin which are commonly referred to as evidence of the planing effects of Glaciers. Glaciers may have rested upon some of these surfaces, but to their action the shelly structure cannot be attributed. Professor Whitney, in his 'Geology of California,' describes domes of greater size than any which I have yet seen in India, but which are otherwise similar. He suggests the same origin for the concentric shells, namely that they have been produced by contraction on solidification.

Two zones of porphyritic gneiss.

Two great zones of this rock occur in Mánbhúm, and in several places inconsiderable areas are occupied by it. A rock which, lithologically, exactly resembles it also

[1] Jour., Roy. As. Soc., Vol. VII, 1843, p. 115.

[2] Scientific Proc., Roy. Dub. Soc., 1880.

occurs interbedded with ordinary gneiss rocks, &c., in many parts of the district.

Birú.

The most northern of these zones has a lenticular shape, and is about 20 miles long. It is first seen south of Dobrajpúr and 3 miles east of the village of Birú on the Raniganj and Purulia road. Here it occurs as a narrow strip, but quickly widens to the west until it extends over about 4 miles. Approaching the Tusurkow river, it again narrows and dies out about 2 miles beyond the river. Throughout this area it rises up in bosses which exhibit the shell structure above alluded to. At Birú it forms a number of picturesque hills, which, as already stated, attracted the notice of Victor Jacquemont; west of that village, too, there are two principal peaks of conical shape which display singular sharpness and grace of outline. The rock forming them is somewhat different from the ordinary kind, the felspar being of a brick-red colour, while ordinarily it is pink or grey. The rock in this neighbourhood is traversed by numerous granite veins and also by a trap dyke. Apparently associated with this rock in very intimate connection are some syenites; they are best seen north of the Birú hill; whether they are of igneous or metamorphic origin it is difficult to say. If igneous, they may possibly have been the immediate cause of the peculiarities of the porphyritic granite. The hill south of Birú does not show the prophyritic structure.

Syenites.

Raghunathpúr.

At Raghunathpúr this rock forms a number of cones and other hills with rugged outlines. Here too the syenitic rock also occurs and an apparently foliated variety of the porphyritic granite.

Sinara.

In some bosses near Sinara also distinct foliation is seen; it strikes from 10° south of west to 10° north of east. Numerous granite and pegmatite veins cross it, running nearly due east and west. North of Mutiala the porphyritic granite is first associated with, and then replaced by, one of the syenitic varieties.

In the neighbourhood of Anara there are some more bosses, some of them exhibit the concentric shell character very distinctly.

Anara.

West of Parakhas the northern boundary of these rocks crosses the Hurie river, just at the junction of the two branches. Close to Haraktur the rock is exceedingly micaceous, and it alternates with the syenite. From this westwards it dies off, appearing to some extent to blend with the ordinary gneissose and granitic rocks.

Parakhas.

The second zone in which this rock is the principal one to occur commences abruptly near the village of Ledurká, about 11 miles east north-east of Purulia; it is there about 4 miles wide, and from thence to the banks of the Subárnárekha, about 40 miles off, it extends without interruption. Beyond the Subárnárekha too, it has been traced for many miles into Lohardaga.

Second zone at Ledurká.

The southern boundary passes through Purulia, in the vicinity of which place and also at Churra, there are some low bosses, but the most remarkable hills within the zone are in the neighbourhood of Jhulda. The accompanying figure of a perfect cone in this neighbourhood will serve to convey an idea of the structure.

Purulia.

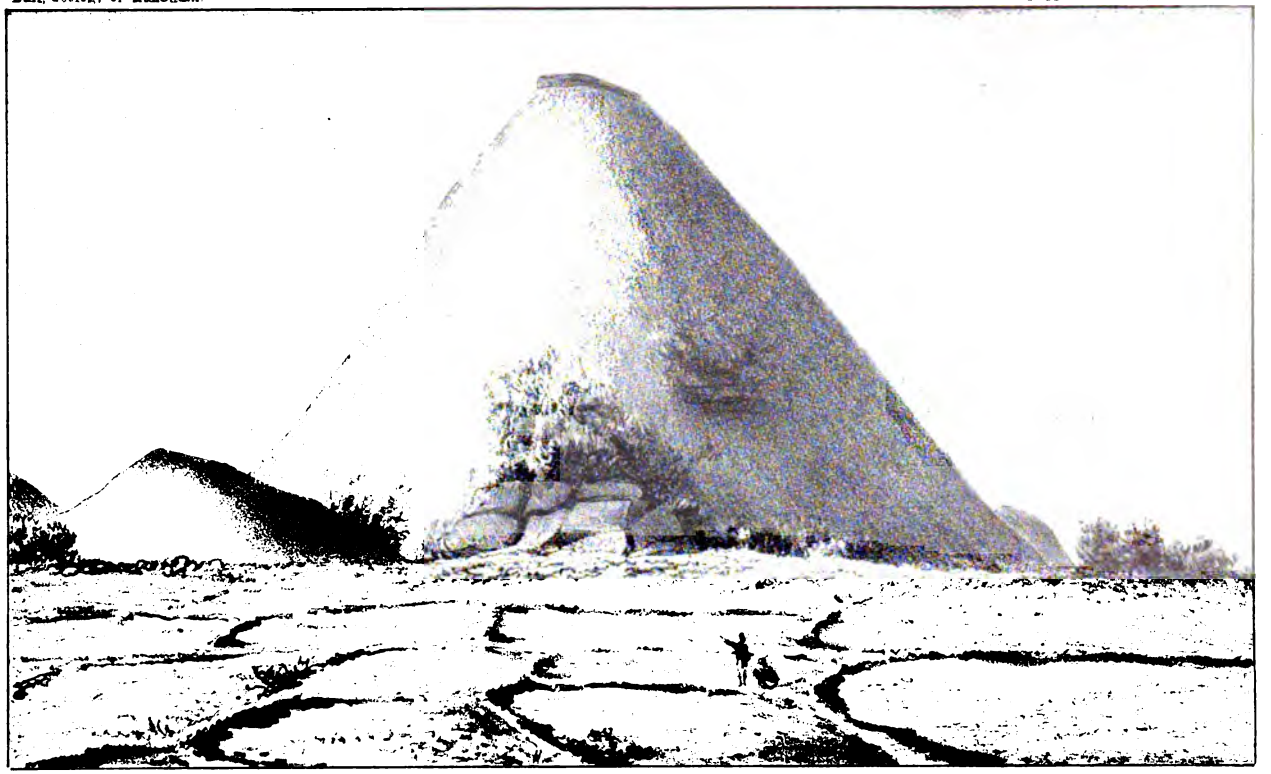
Jhulda.

The abrupt commencement of this zone near Ledurká suggested the possibility of its being cut off by a fault, but the only similar zone is that just described which passes through Raghunathpúr, and if these were ever in contact, the fault must have been an enormous one with a throw of at least 10 miles—a supposition not to be entertained except on the very strongest evidence.

Possibility of a fault.

As to the possible igneous origin of this rock, I am inclined to think that there is no evidence which can be considered as even rendering it more than just possible. At the same time these zones seem so independent of the surrounding rocks, that it is difficult to regard them as forming only a part of the ordinary series.

Origin.



J Schaumburg, Lith

CONICAL BOSS OF PORPHYRITIC GNEISS, NEAR JHULDA.

North of the 2nd zone, the alternations in character are frequent. In addition to granitic gneiss there are quartzites and hornblendics. Some of these quartzites when accompanied by schists, of which a small proportion occurs, are not readily distinguishable from sub-metamorphics, but they seem to be interbedded with gneiss, from which they are therefore inseparable. North of these there are alternations of granitic and porphyritic with occasional bands of garnetiferous gneiss, beyond which are rocks similar to those of the Tusurkow section.

Rocks north of 2nd zone.

Section.

South-east of Purulia there is a remarkable change in the strike from east and west to north and south. This evidence of disturbance does not show in the zone of porphyritic gneiss, as it might be expected were the rocks all of the same age and origin. Between the zone and the Bhagmundi plateau, granitic rocks crop out occasionally through the alluvium.

The Bhagmundi plateau embraces an area of about 90 square miles, bounded, for the most part, by steeply scarped cliffs. At the angles there are a few detached conical hills, some of which are familiar objects, being distinguishable for considerable distances, that known as Kankiboro, is said to have been formerly used as a sacrificial altar by the Sonthals. But it is rather a puzzle how the priests and their victims succeeded in scaling the steep cone.

Bhagmundi plateau.

The plateau is formed principally of coarse granitic gneiss: hornblendic bands occur, but are rare. From its base the former may be traced eastwards for a distance of about 12 miles, when they take a sudden and abrupt bend to south, and this strike is continued to within 3 miles of the great fault, when it again turns to east, and the rocks, though shifted by the cross fault, can ultimately be traced till they disappear under the alluvium.

Formed of granitic gneisses.

Near Hęsla the rocks are granitic gneisses containing a black mica. In the Subánárekha section between this and the fault there are granitic gneisses and some schists, the latter much contorted.

Detached from the general area occupied by the rocks of the metamorphic series, there are two outlying tracts, as already mentioned on pages 21 and 23, in which the rocks are referable to the same series. One of these is situated in the neighbourhood of Barabazar, and the other lies to the east and south-east of Koelapal.

In the latter, the rocks are chiefly schists, but interbedded with them at Raipúr and Koelapal there are some granitic gneisses which are sufficient to indicate the affinities of the whole. Towards the south these rocks pass across the boundary into the district of Midnapúr, and on the east they become speedily covered up by alluvium.

CHAPTER VI.

Section 1.—Igneous Rocks.

The want of a crucial test by which igneous can be distinguished from metamorphic rocks, whether granitic or hornblendic, has been alluded to on page 29. Instances in which doubts have arisen as to the character and origin of particular exposures of these rocks are of frequent occurrence.

In a report on a portion of the district of Házáribágh[1] I described the granites of that area as being divisible into three varieties, *viz.*:—

a.—Unfoliated granitic gneiss.

b.—Interbedded granite which is accompanied by local alteration and contortion. Its strike generally, if not always, coincides with that of the gneiss. In age it is probably contemporaneous with the metamorphism.

c.—Lode granite traverses the gneiss and associated rocks in directions corresponding to those of the joints or their conjugates. It also occurs where there has been local crushing up or contortion.

To these three varieties I would add, in Mánbhúm with some hesitation, true igneous granite, including in it certain granites which occa-

[1] Mem., Geol. Surv. of India, Vol. VI, pt. 2.

sionally appear quite independent of the strike of the metamorphic rocks. It were useless to enumerate in full here cases of the occurrence of such rocks in Mánbhúm, and impossible to attempt any distinctive representation on the map of these different varieties. In order to prepare such a map of so large an area much more time would still have to be devoted to minute detailed examination.

The most notable instances of granite or granitoid rocks occurring apparently independently of the surrounding rocks are *1st*, the porphyritic granites described on pp. 36 to 38, *2nd*, the granitic syenite of Tilbani and Sindarpúr hills, and *3rd*, a very fine igneous-looking granite forming some hills about 4 miles to the west of Súpúr.

As mentioned on the preceding pages, syenites of equally doubtful origin occur occasionally.

Of trappean rocks, there are abundant dykes of diorite and greenstone, more particularly in the northern and eastern parts of the area. On page 32 a peculiar gabbro is described: there can be no doubt, I think, that it is of igneous origin.

Besides these there are the hornblendic rocks whose anomalous characters have suggested the probability of their having been, like some of the granites, intruded at the time of metamorphism. They were to some extent possibly also agents of the metamorphism.

There is a doubtful case of overlying trap at Ankadora and several other localities, but no clear instances of trap capping hills.

Section 2.—Faults.

The principal faults in Mánbhúm may be classified in several series according to their directions. Such classification is not intended necessarily to imply contemporaneity under each head. These series are—

1. East to west.
2. North-west to south-east.
3. North-east to south-west.

East and west faults.—To this system belong the principal faults of

Mánbhúm. The most northern example is that which, with its branches, forms the southern boundary of the Raniganj coal-field. One of these branches is possibly connected with the fault forming the southern boundary of the Jharia coal-field, while another branch starting from Baharinath proceeds westwards, and is traceable as far as Deoli.

The next fault is marked by a line of disturbance which runs north of Jaipúr. Some small unimportant faults of this system occur scattered about the district. Of these, some bound outlying patches of the sub-metamorphic rocks, and others occur in the granitic gneiss, where it is difficult to estimate their precise effects.

The next large east and west fault is that which bounds the sub-metamorphic rocks on the north. It has been fully described on page 16.

Further south, in the vicinity of the trap dyke, there is also a fault with the same general direction.

North-west to south-east faults.—Next to east and west the line of north-west to south-east appears to have been a principal one of disturbance.

Both in the metamorphic and sedimentary rocks faults of this system occur, and the largest trap dykes of the district, indicating lines of fracture, also strike in the same or approximately the same direction.

Faults from south-west to north-east are of rare occurrence, only one case in the metamorphic rocks having been clearly established.

Faults belonging to other systems are of minor extent, and chiefly occur in the sedimentary rocks of the coal-fields. Where they affect coal seams they may have a considerable economic importance.

CHAPTER VII.

Section 1.—Minerals.

The rocks of Mánbhúm having been unopened by artificial cuttings, the number of minerals which have been obtained is exceedingly scanty.

The following are the principal which have been identified as occurring in the metamorphic rocks:—

Actinolite.
Hornblende.
Pyroxine.
Tremolite.

Kyanite.
Fibrolite.
Andalusite.

Orthoclase.
Oligoclase.

Epidote.
Garnet.
Idocrase.

Chlorite.
Serpentine.
Steatite.
Talc.
Schorl and Tourmaline.

Common mica. (Muscovite.)
Margarodite.
Black mica Biotite.?
Green mica.

Calcite.
Dolomite.

Quartz.
Jasper.
Chert, &c.

Ores.
Red and brown hæmatite.
Magnetic iron.
Pyrites.
Ilmenite.

Molybdenum sulphide.
Argentiferous galena.

Copper oxides and carbonates.
Gold.
Graphite.

The following analyses of rocks and minerals from Mánbhúm were made by the late Mr. Ormsby [1] when at home on sick leave.

Metamorphics.

(1). *Porphyritic gneiss* 25grs. ignited=24·80.
∴ H. O. = ·20.

	Per cent.
SiO_2	67·60
Al_2O_3	14·16
Fe_2O_3	8·00
Mn_3O_4	0·84
CaO	2·68
MgO	0·84
KO	4·40
NaO	2·68
	101·00

[1] *Vide* Jour., Roy. Geol. Socy. of Ireland, New Series, Vol. III, p. 26.

This rock consists mainly of quartz and black mica with orthoclase crystals included in it so as to produce an amygdaloidal porphyry.

(2). *Felspar from the above* 25 grs. ignited=24·91.

∴ H.O. = ·09.

	Per cent.			
SiO_2	65·04	1·44		4
Al_2O_3	19·60	0·38		1
CaO	0·89			
MgO, a trace			38	1
K. O.	12·60			
NaO	2·48			
	100·61			

Orthoclase.

(3). *Stratified gneiss.*

SiO_2	69·00
Al_2O_3	18·76
Fe_2O_3	1·40
CaO, CO_2	2·35
NaO	6·12
KO	1·31
HO	1·20
	100·14

This rock occasionally contains garnet, schorl, and epidote. Its principal constituents, oligoclase and margarodite, have the following compositions:—

(4). *Felspar from the above* 25 grs. ignited=24·85

∴ H.O. = ·15

SiO_2	64·20	1·42		3
Al_2O_3	22·84	·44		1
CaO	3·13	0·11		
MgO trace			0·41	1
K.O.	0·84	0·02		
NaO.	8·72	0·28		
	99·73			

Oligoclase.

(5). *Mica (white) from the above* 25 grs. ignited=24·1
∴ H.O.= 0·9

SiO_2	45·60
Al_2O_3	31·24
Fe_2O_3	6·40
CaO	0·24
MgO	0·84
KO	10·44
NaO	1·00
HO	3·60
	99·36

Margarodite.

SUB-METAMORPHICS.

(6). *Potstone (vessel).*

SiO_2	54·60	1·213	1·213
Al_2O_3	5·08	0·098	
Fe_2O_3	6·24	0·173	
Mn_3O_4	0·64	0·020	1·743
CaO	0·24	0·008	
MgO	28·88	1·44	
HO	4·00	·444	·444
	99·68		

SiO_2 = 1 2
RO = 1·44 3 } 3 RO, 2 SiO_2 + $\frac{2}{4}$ H.O.
HO = ·36 $\frac{1}{4}$

Section 2.—Economic Resources.

Coal, iron, gold, argentiferous galena., copper, limestone, dolomite, building and paving stones, potstones, slates, kaolin, road metalling.

COAL.—The coal of Mánbhúm is all contained within the limits of the Damuda valley areas which are known as the Raniganj and Jharia (Jharia) coal-fields. These fields having formed the subjects of separate Memoirs, it is only necessary here to refer the reader to them for all information regarding the coal found in this district.

IRON.[1]—A variety of different ores of iron occur in Mánbhúm.

The clay iron ores of the ironstone-shale group of the Damuda series in the Raniganj coal-field have frequently been described.[2] The result of analysis of 29 specimens from many different localities in the field gave an average percentage of 38·92 of iron. It is pointed out that good iron might be produced by mixing them with the ores of magnetic iron procurable in the neighbouring metamorphic rocks.

In the Jharia coal-field Mr. D. Smith formed an unfavourable view of the iron. He writes: "The strata are very disturbed with every appearance of an unimportant deposit of ore." Mr. Hughes also says that the quality of the ironstones of the ironstone shale group is very poor; they are so siliceous that the native Kumars can do little with them. The remainder of the area is, with the exception of one spot, barren with respect to iron ores. This is east of Bundkurma, where "some extremely ferruginous concretions in red micaceous clay shale are employed in a furnace near Teelaya."

Magnetic iron ore is chiefly found in the beds of dried up streams and nalás, where, as a black sand, it accumulates in hollows and underledges of rock. From these situations it is scraped up and laboriously collected until a sufficient quantity is obtained for charging a furnace. In this form, as sand washed from the metamorphic rocks, it is found in almost all parts of the area.

When *in situ* it is generally found in quartz veins, often, but by no means exclusively, in those which occur in the sub-metamorphic rocks. In the metamorphic area, the most considerable accumulation of it observed occurs in the hill near the village of Telúdi, close to Baharinath. It also occurs disseminated in many varieties of gneissose rocks,

[1] These notes were written several years before the late Bengal Iron Works Company commenced operations.

[2] See Mem., Geol. Surv. of India, Vol. III, pt. I, and Mr. D. Smith's report to the Government of India, pp. 74-77 and 194, on the Coal and Iron Districts of Bengal. Also see later papers on this subject by Mr. T. W. H. Hughes, Rec. of the Geol. Surv. of India.

but nowhere has it been observed in very great quantity and purity. Titaniferous iron, or ilmenite, occurs also, and the excellent quality of some of the iron which is manufactured by the natives is not improbably due to the presence of this ore mixed with the magnetic iron sand. The best specimens of this ore were obtained at the foot of the hills west-north-west of Manbazaar. It occurs both massive and in thin plates.

Red and brown hæmatite.—The hydrous peroxide of iron, or brown hæmatite, occurs principally along the lines of fracture. It appears to have been infiltrated amongst the broken debris of the edges of the faults. Subsequently, as has been pointed out on page 16, it has in many places been replaced by silica, giving rise to the peculiar pseudomorphic quartz which has been described. As in most metamorphic areas, it also occurs in the rocks themselves more or less abundantly. Red hæmatite is of much rarer occurrence, but it is far from being absent.

Many of the localities in which brown hæmatite occurs on the faults have been indicated on page 17. The principal places where it occurs are, Ambikanagar, Khatrah, Púrdá, Sinderpúr south of Mátá, Choroboro, Jhonjka, &c.

From the abundance of heaps of slag occurring throughout the district, it is supposed by some that the manufacture of iron was at one time carried on with more activity than it is at present. But it should be remembered that the knowledge of manufacturing iron is of considerable antiquity, and that these accumulations of slag may be due rather to the long periods at which the smelters have been at work than to there having been great numbers of them employed at any one time.

The furnaces and system of reduction at present in vogue are of the simplest kind, much more simple even than in the adjoining district of Birbhúm.

Gold.—In a paper [1] specially devoted to the subject, I have described the mode of occurrence of gold in Singhbhúm and Mánbhúm, and traced its connection with the rocks of both district.

[1] Rec., Geol. Surv. of India, Vol. II, p. 11.

It is found in the detritus and superficial deposits which cover both the metamorphics and sub-metamorphics, but by actual trial it was found to be from 2½ to 3 times more abundant in the latter than it is in the former.

The most favourable localities for washing the sands are generally in the vicinity of magnesian schists, and it seems probable that from these rocks and their contained quartz veins most of the gold is derived.

The native gold-washers confine their operations within the sub-metamorphic area, traditional experience having established the limits wherein washing is remunerative. They do not, however, connect the presence of gold with the vicinity of any particular rock, not even supposing it to be derived from a rock. They belong to the lowest and poorest races in the country. Their average daily earnings are about one anna.

For further information the reader is referred to the special paper on this subject printed in the Records, also to the remarks on Singhbhum gold in the present volume. On the map accompanying this report, actual localities where gold-washing is known to have been successful will be found indicated.

ARGENTIFEROUS GALENA.—The occurrence of a lode of argentiferous galena in Mánbhúm has already been described at some length,[1] so that it is only necessary to refer here to the principal facts.

The lode is situated on a hill formed of mica schist, which is close to a *dih* called Jani-jour, where there is an outlying house of the village of Dekia, which lies about a mile east from Dadka. As it has not yet been opened up, nothing definite is known regarding its extent and limits.

According to an assay made by Mr. Tween, the silver in the galena is in the proportion 119 oz. 4 dwt. 16 grs. per ton of lead. Antimony is also present in this ore. During the present year (1881) a preliminary excavation of this lode has been made in order to ascertain its extent.

COPPER ORES.[2]—Traces of copper carbonates occur in old excavations

[1] Rec., Geol. Surv. of India, No. 3, 1870, p. 74.
[2] *Idem*, p. 76.

1 mile north-east of the village of Púrdá (Poordah), parganá Mánbazaar, or about 30 miles from Púrúlia, and also near the village of Kuliánpúr. Neither of these promise to yield copper in workable quantity. In various other localities I heard of copper having been found, but in these two alone were there any traces visible. Reference will be made to these deposits on a subsequent page in connection with the copper of Singhbhúm.

DOLOMITE.—The outcrop of a *vein* of magnesian limestone or dolomite is visible near the village of Ramlallpúr, about 4 miles south-west of Medjia; it is traceable for about 50 yards along a north to south strike, and is from 16 to 20 yards wide. It exhibits the characteristic mammillary structure of dolomite, and is dendritically marked in several places. It contains some veins of bitter spar. A vein of crystalline dolomite near the copper ore on the great fault close to the village of Púrdá has been mentioned on page 17.

LIMESTONES.—The principal source of lime in Mánbhúm is *kankar* or *gúlin*, which occurs throughout the district, but most abundantly in the northern and eastern portions.

On a preceding page (34) the existence of calcareous schists with veins of crystalline limestone in the gneiss west of the Rániganj coal-field has been alluded to. Besides these, limestone occurs, but apparently only in small quantity, on the southern fault of the Rániganj field. The former afforded a supply of lime which was used as a flux at the Bengal iron works. A somewhat promising source is a kind of grey limestone or marble which occurs within the coal-field at the north-west corner of the base of Pachete; the supply is probably not unlimited, but would prove considerable. It was also used but was in parts too silicious as a flux.

Occasionally in this district, but more abundantly in Singhbhúm, a kind of calcareous tufa derived from former hot springs is found in crevices in the hills. It is commonly spoken of by the natives as *Asarkar*, or giant's bones. It also occurs in the Rájmahal hills, and is there burnt for lime.

BUILDING AND PAVING STONES.—The only stone at present largely quarried and used for building purposes is the coarse sandstone at Barákar. It has been used for public buildings in Calcutta, as well as locally for the Barákar bridge and the railway. It is of very unequal quality and texture, and has been proved to be incapable of sustaining great pressure. For all ordinary building purposes, however, it is very useful.

The quartzites and felspathic quartzites or granulit[1] which form Sasuniá hill have long been quarried and manufactured into flags, curb-stones, &c., and are known in Calcutta as Bardwán paving stones. The outturn and despatch to Calcutta of dressed stone has at times reached 12,000 square feet per mensem, but it is often less than one-fourth of that amount.

At the time of my visit (December 1866) there were twenty-five quarries on the northern face of the hill and a somewhat smaller number on the southern: only a few of them were open, the number of workmen having been more than decimated by the famine and fever which had prevailed in the neighbourhood.

The custom adopted is to work each quarry by a separate family or clan. In some of these parties every individual had died. In others the few that remained were unable to undertake the work alone, and being averse to join with strangers remained out of employ.

Quarrymen can earn from 4 to 10 annas a day and coolies from 2 to 4 annas. Women by making six journeys and bringing down that number of dressed flags can make 3 annas.

The ordinary flags are 2 feet square, being 4 inches thick, but special contracts are undertaken for particular sizes.

An improvement on the present system would be to open up quarries at the base of the hill and so save the expense of carriage and waste of labourer's time caused by the elevation of the present works.

There can be little doubt that equally good stone would be obtained as the dip of the rocks in the quarries on the south face would just

[1] Occasional bands of mica occur, producing a locally schistose structure.

bring them down to the northern base. Precautions would have to be taken to prevent the rubbish from above rolling into and filling up the works.

A rock of similar character to that of Sasuniá occurs in the south part of the district, but it is not nearly so accessible.

A considerable variety of gneisses, metamorphic granites, &c., occur in Mánbhúm which would be suitable for building purposes.

POTSTONES.—Throughout the sub-metamorphic area magnesian schists are of common occurrence; they vary considerably in texture and composition. There are talcose and chloritic schists, soapstones, and potstones; many of the varieties are quarried and manufactured by means of rude lathes into plates, curry-dishes, basins, and *Máhádeos*. One variety is not much esteemed owing to its inability to sustain heat. This is probably due to the presence of chlorite, which contains a larger percentage of water of combination than the talcose minerals. The cracking of this variety is therefore doubtless caused by the liberation of this water when heat is applied. Before the famine a very large number of these articles used to be despatched to Bardwán and elsewhere, and in fact this was one of the principal indigenous industries of the district, very profitable to all engaged in it save the poor artificers, who by the common system of advances become little better than slaves to the Mahajans.

At the time of my visit many of the quarries were still worked, but not so actively as they appear to have been formerly.

The following are the principal localities in the sub-metamorphic area where these quarries are situated:—

VILLAGE.	PARGANA.
Jogidih	Phulkusma.
Mutgoda	Samsunderpúr.
Sarusbad	Ditto.
Bogra	Raipúr.
Gopalpúr	Súpúr?
Pokarhatu	Kuliapal, East.
Ellora	Ditto.
Jabla	Ditto.
Bandgáon	Ditto.

Village.	Pargana.
Khurbunni	Kuliapal, East.
Punsa	Barabhúm.
Gendoa	Ditto.
Pardih	Ditto.
Semua	Ditto.
Barahatu	Patkúm.
Moisara	Ditto.
Aranga, &c.	Ditto.

Besides the above, there are in many places deserted pits and quarries. In the metamorphic rocks, at a few scattered localities, there are also some potstone quarries.

Kaolin.—The decomposition of the felspar in the granite veins, which occur so abundantly throughout the gneiss, and in some of the gneisses themselves, produces a considerable amount of impure kaolin. The felspar porphyry rocks which occur 7 miles south of Ráníganj produce a pure and clean kaolin in some abundance.

Slates.—In the foregoing account, allusion has been made to the existence of slates which exhibit cleavage. In all of these lamination is present, and therefore the cleavage cannot be availed of. Laminated slates of from $\frac{1}{4}$ to $\frac{3}{8}$ an inch in thickness might, I think, be obtained in the sub-metamorphic rocks, towards the south of the district.

Road metalling.—The best quality is obtained from the numerous trap dykes which traverse the area. At one time metalling for Calcutta was procured from some of the dykes in the neighbourhood of the Ráníganj and Bankúra road.

At present the supply for Calcutta is obtained from Udwa-nalá near Rájmahal, where there is a spur of the Rájmahal hill trap conveniently situated near the river.

The railroad and grand trunk road are generally supplied from the nearest available sources of laterite, trap, quartz, granitic gneiss or even iron ore.

II.—SINGHBHÚM.

Introduction.

Political divisions.

The district of Singhbhúm is politically divided into the Kolhán or Hodesum, which is inhabited by the Hos or Larká Kols; and Singhbhúm proper which contains the estates of the semi-independent chieftans of Saráikálá, Kharsawán and that of the former Porahat chief, who forfeited his territory for misconduct in 1857. To the north-east the pargana of Dhálbhúm is situated; it separates Singhbhúm from Mánbhúm and Midnápúr. Its chief is also semi-independent.

When examined.

The examination of the part of Singhbhúm included in the present map, was accomplished in the season 1868-69, with the exception of a small portion to the west of Chaibassa, which could not be completed then on account of sickness. An opportunity for doing so occurred in 1874-75, when the writer was marching to examine the Ráigarh and Hingir coal-field in Gangpur and Sambalpur. This served to square up the tract to about the 22° 30′ parallel of north latitude, south of which, except in the valley of the Subarnarekha, up to the present, no geological survey has been made. In the year 1870 a brief sketch of the geology, in connection with a detailed account and map of the copper-bearing rocks, was published; but the present more complete account was kept back awaiting the time when the remainder of Singhbhúm and some of the adjoining districts south of the 22° 30′ parallel could be examined and the results incorporated.

As, however, there is no immediate prospect now, in consequence of other more urgent calls elsewhere, of this work being undertaken, the following description of a part of Singhbhúm is given in connection with that of the district of Manbhúm, the result of the combination being that the map represents a well-defined, compact and rectangular area, the geology of which is very intimately connected throughout. It should be added that adjoining portions of the following districts are

included in the map—Hazaribagh, Birbhum, Bankura, Midnapur, and Lohardaga.

The maps which were used during the geological survey of Singhbhúm were photographs of those by the Topographical Survey on the scale of half an inch to a mile, the since issued maps on the scale of 1 inch to a mile not being then available.

Map.

The present map issued with this report, which is a transfer from the Atlas sheets Nos. 113 and 114, on the scale of one inch to 4 miles, embraces an area of between 11,000 and 12,000 square miles.

CHAPTER I.

Previous Notices.

The district of Singhbhúm, though imperfectly known to the general public, has been more frequently examined geologically than many more accessible and important localities in India.

It often happens in this country that the geological surveyor has to examine a district unaided by a single trustworthy observation made by a local observer, so that it is with much gratitude I record the assistance which I have received from the published geological notices of Singhbhúm.

Taking these notices in the chronological order of their publication, the first is Colonel Tickell's paper on the *Hodesum*,[1] or country of the Hos.

Lieutenant Tickell, 1840.

He notices the parallel character of the ranges of hills, of which the loftiest, he states, appear to be 1,000 feet above the plain: "They are chiefly quartz in all stages of decomposition permeated by limestone rocks; smaller detached ranges issuing at right angles to these are commonly of micaceous slate."

Whether by the limestone thus mentioned is meant the limestone schist which is found at Chaibassa and in Songra, it is impossible to say; there is certainly no limestone in the district which can be said to *permeate* the quartz.

[1] Jour., As. Soc. Ben., Vol. IX, p. 694.

He further mentions banded jaspers which are seen in the bed of the Baiturni river. Corundum is stated to occur in great quantities at Jagannathpur. The material so called does not appear to have been true corundum, possibly it was massive garnet or calderite. Coloured clays occur in several streams and are highly in request amongst the natives.

Gold occurs in the streams; but the Hos do not know how to collect it, though their neighbours in Singhbhúm obtain a tolerable quantity. Iron of excellent quantity is obtained. Of coal, no traces were found.

Dr. Voysey's journal[1] contains some notes on the character of the rocks in the neighbourhood of his route, which lay, so far as the present area is concerned, from Chakardhapur *viâ* Saráikálá, Edol, &c., up to Kuliapal in Manbhúm.

Dr. Voysey's Journal, 1823.

He saw "a kind of claystone lying in a bed in the gneiss near the Sonjai; this change is analogous to that which takes place in the granite at Hyderabad from greenstone to potstone." It is not quite clear what is meant by the first part of the sentence; possibly it may refer to a case of local metamorphism, but more probably he struck the boundary, which, as may be seen by a reference to the map accompanying this report, sharply separates the granitic gneisses from the clay slates, &c., close to the locality indicated.

The following remark, confirmed as it has been by the discovery of argentiferous galena in the quartz veins which traverse the schists near Dhadká, by the existence of copper ores in the schists within a few miles of the locality to which Dr. Voysey refers, and by the occurrence of Manganese, iron and gold in other parts of the district, is well worthy of quotation. "Numerous large beds and long veins of white quartz; "it is not improbable that metalliferous ores exist in this rock. It has "been found the richest in metals of all the Indian rocks. At Callastry "it contains lead ore mixed with silver; at Nellore copper; at Nagpur "Manganese, lead ore and copper; micaceous iron ore is a common "product of this rock."

The granite at Saráikálá resembles that in some parts of the province

[1] Jour., As. Soc. Ben., Vol. XIII., 1844, pages 861 and 862.

of Hyderabad. Between Idhull (Edol) and Bagmará he noted "the "concentric granite passing into gneiss and numerous trap veins." At Narsinghpur plates and cups were being manufactured from the chloritic schists. The pass of Narsinghpur is of mica schist passing into clay slate.

Colonel Haughton, 1854.

Colonel Haughton's memorandum "On the geological structure and "mineral resources of the Singhbhúm division,"[1] accompanied by a map, contains much valuable information.

The general characters of the physical geography and geology are briefly described. Colonel Haughton recognises the existence of two formations. He describes them as —

1. Gneiss passing in some places into granite.
2. Schists, slates, old sandstones, and others 'which may be called metamorphic rocks.

"The appearance of these rocks varies greatly according to their "proximity to the igneous rocks which underlie, overlie, or pierce "them."

The granitic trap-traversed area which lies east of Cháibásá seems to have been regarded by Colonel Haughton as one in which the rocks were thus locally affected by the trap; and on his map it is accordingly coloured with the same shade as the slates, &c.: with this opinion I cannot agree, as will appear in the following pages; the rocks are possibly modified by the trap of a small extent, but they undoubtedly belong to the oldest metamorphic series.

The principal object of Colonel Haughton's paper was to draw public attention to the mineral resources of the district; and in this he was successful, as it led to the formation of the Singhbhúm Copper Company. As it will be necessary again to allude to Colonel Haughton's paper when speaking of the economic resources, we shall now pass on to note those of Dr. Emil Stœhr.

Dr. Stœhr, 1855.

Dr. Stœhr came to India in the year 1855 at the request of two Calcutta firms to examine the copper-bearing rocks to which Colonel Haughton had drawn atten-

[1] Jour., As. Soc. Ben., Vol. XXIII.

tion, and to assist in the formation of a Company, should his report recommend it.

After his return to Europe, Dr. Stœhr published two papers[1] in which, besides accounts of the copper deposits, the neighbouring rocks are also described. To the more important of his very valuable remarks and observations, reference will be made in the course of the following pages.

Durschmidt, 1857.

A pamphlet by Mr. Durschmidt, one of the promoters of the Company, reproduced Colonel Haughton's map, &c.

V. Ball, 1870.

As has been already mentioned in the introduction, a paper by the present writer,[2] descriptive of the copper deposits, also gives a brief sketch of the geology: with this paper printed translations of portions of the two papers by Dr. Stœhr which have just been alluded to were also issued.

CHAPTER II.

PHYSICAL FEATURES.

Section I.—Hills.

On the north-west Singhbhum is bounded by a portion of the Lohardaga or Chutia Nagpur plateau, from which there is a somewhat steep descent into the low-lying plains of Singhbhúm. The various routes, one of them being a made road, traverse the spurs with intervening valleys into which the plateau becomes here broken up. The extension of two of these spurs is marked by hill ranges, which continue for a distance of about 70 miles to the south-east, after which they gradually break up, the rocks forming them, finally disappearing under the alluvium of Midnápur.

Northern Spur and Range.

The more northern of these prolongations of the spurs, if they may so be called, has been already alluded to in the foregoing description of Mánbhúm. It may be

[1] Viertel. der Nat. Gesell. Zurich, 1860, Vol. V., p. 329., and Neues Jahrbuch fur. Min. Geo. u. Pal., 1864.

[2] Records of the Geol. Survey of India, Vol. III., p. 86, with a map.

well here, however, to indicate its leading structural features throughout. It is made up of three subordinate ranges, which are separated by well-marked valleys where the softer rocks have been eroded away. These ranges are formed respectively of trap, quartzite and schist. The hills

Trap.

formed of the trap range attain the highest elevations, its principal peaks, west of the Subarnarekha, being Chatwa 2,673, Bicha 2,776, Tatkora 2,910, Nanji 2,491, Kirda 2,772, Pandu 2,778, Desan 2,760, Sindurhuli 2,924, Jojo 2,836, Sawai 2,331, Girgirali 2,529. Besides these there are a number of other peaks upwards of 2,000 feet high. As the valley of the Subarnarekha is approached, there is a somewhat gradual descent till the hill marked H. T. 185 is reached, after which there is an abrupt descent to the level of the bed of the river.

East of the Subarnarekha, a gradual rise attains, within 11 miles, to the highest elevation—Dulma—3,050 feet. Thence eastwards, the elevation is inconsiderable. Although this range contains peaks of such varying heights, the general effect, when viewed from a distance in Mánbhúm, is as of a range of uniform or but little varying height. This trap has shared in the dislocation to which the rocks generally have been subjected on the borders of Midnápur and in the hilly disturbed area which lies north-west of Sildá.

South of the trap there is a range formed of quartzite, which, being

Quartzite.

in some places felspathic, might be called *granulit*. This is not very well seen west of the Subarnarekha, where it seems to thin out gradually; but east of the river it forms a continuous range, the peaks of which are from 1,000 to 1,500 feet high. In the extreme east, greater heights are attained—as in Dharagiri 1,738 feet and Lakesini 1,636 feet.

The southern range is formed of micaceous and talcose schists, both

Schists.

this and the preceding contrast with the trap range in being broken up by frequent gorges which occur at intervals of every few miles, such passages for the drainage being very rare in the trap range.

The map, north of Ghatsilla, illustrates clearly the effects of the crushing up to which these ranges have been subjected, the cause of this crushing, as well as of the twisted and contorted state of the rocks in the north-west corner of Midnápur, appears to have been connected with the elevation from beneath of the older metamorphic rocks which occupy the south-east corner of Mánbhúm.

Subordinate Ranges.

Although these ranges are the principal components of the spur, it is not composed of them alone. On the northern flank there is a much broken range formed of conical hills of blue slates and some thin-bedded quartzites. North of these, too, at a short distance, there are some hills formed of quartzites and slates, and an outcrop of a remarkable chert-like quartzite, which forms a line of low hills.

Southern spur.

The second spur leaves the plateau at a point about 9 miles south of the other, whence it pursues a steady eastern direction for a distance of 42 miles, and then sweeps round to south-east and south. Near its starting point from the plateau this spur is much broken up into small detached ranges of hills between which wide valleys intervene. Between Narangpur and Rajdoha these ranges are larger, and approximate more closely to one another; but it is only in its extension to the south-east of Rajdoha that this spur acts as a distinct water-shed.

The principal rocks forming it are mica schists with quartzites; but towards the south-east there are several runs of interpolated trap. The total thickness of the quartzites is much increased, too, in that direction.

The principal peaks on this spur are Lopso 1612 feet, Okam 1,398 feet, Dholia Chundar 1,107 feet, Sidheshar 1,477 feet, Kapargadi 1,651 feet, Kujundi 1,676 feet, Salberia (1) 1845 feet, Salberia (2) 1,799 feet, Dalma 1,676 feet. In the schists of the northern flank of these hills the copper ores of Singhbhúm and Dhálbhúm occur.

Between these two spurs there is a belt of inhospitable, sparsely-populated jungle land; the soil is exceedingly poor and unproductive. It is studded with small hills which are formed principally of horn-blendic schists.

Central granitic gneiss area.

South of the second spur the granitic gneiss area of Central Singhbhúm is at once entered upon. On the north, east, and west, and probably to a certain extent on the south, it is cloaked round by ranges of hills formed of the submetamorphic rocks which seem for the most part to rest naturally on the granitic rocks. This area is traversed by a net-work of trap-dykes, the most important of which form very definite ridges, one of them rising to 1,997 feet, or about 1,200 feet above the plain.

The granitic gneiss rocks traversed by these traps being much decomposed at the surface are for the most part obscured by recent superficial deposits, but occasionally they appear through these, showing a characteristic bossy, dome-like form. To the west of this central area, and intervening between it and the highlands of Porahat, there is a tract in which both metamorphic and sub-metamorphic rocks occur, as will be described in detail further on.

Korkai river.

Section 2: Rivers.—The drainage of the western portion of the country, south of the second spur, is effected in a northerly direction by a fine river called the Korkai or Kodkai, which measures from its source to its junction with the Subarnarekha upwards of 100 miles. The direction of its course throughout is, northwards, whereas the Subarnarekha runs south-eastwards, the valleys of the two rivers being separated by the second or southern spur.

The principal tributaries of the Korkai are the Ili, Raro, Sonjai, Sona, and Bongbonga.

The eastern portion of the area is drained by a number of small rivers and streams, the principal of which are the Gurum, Gurrha, Gharmorá, and Sonk.

Pools in river-beds.

Many of the smaller and all the larger rivers in this area are characterised by having deep pools at intervals; these are sometimes half a mile long; a considerable depth of water remains in them even in the dry weather, when the running portion of the stream itself almost disappears. This feature I have not noticed in the rivers of the adjoining districts of Manbhúm and Hazáribágh, but it is common in Sargújá.

CHAPTER III.

General Geology.

Section 1.—Formations represented.

It is not in consequence of any great variety in the formations represented, that the geology of Singhbhúm is so interesting a subject for examination. So far as the evidence goes, this part of India, during the time that the Vindhyan and Gondwáná rocks were being deposited in the lakes or rivers of other parts of the peninsula, was dry land and was being subjected to the influences of sub-aërial denudation and erosion. There is nothing, moreover, in the present configuration of the ground to show that at any time it was acted upon by the sea, nor has the slightest trace of any marine organism been found in the recent or sub-recent superficial deposits.

No sign of marine erosion.

There are also no signs of the flows of Deccan trap in early tertiary times having spread so far to the east. In short, excepting the older metamorphosed rocks, the only formations occurring here which are also found in other distant parts of India are the superficial deposits including laterite.

Deccan trap absent.

The formations occurring in Singhbhúm are all included therefore under the following heads:—

Superficial Deposits.
Sub-metamorphic Series.
Metamorphic.

The rocks of igneous origin which cannot strictly be said to constitute a formation will be described separately.

Section 2.—Superficial deposits.

Alluvium—Gutin or Kankar—Tufa—Laterite.

Alluvium.—There is little to be said under this head; the usual disappearance of the rocks under the laterite and alluvium takes place on

the east. The granitic areas are in a great measure obscured by local spreads of alluvium, but in the sub-metamorphic areas such spreads are comparatively rare.

Gutin or Kankar.—The ordinary gutin or kankar occurs very abundantly in certain places, but more particularly in the alluvium which, as just mentioned, rests on the gneiss. In the bank of the river at Cháibásá a deposit of gutin forms a bed which was said to have yielded bones, but none were obtainable at the time of my visit.

Tufa.—A tufa deposit from springs occurs on the quartzite range north of Bansiderah; it will be necessary to allude to it again further on as a source of lime.

Laterite.—Whatever the influences were under which this puzzling rock originated in other parts of the peninsula, it is certain that Singhbhúm was not exempt from them. It occurs both at high and low levels, and by doing so supports here, as in other areas of Chutiá Nágpúr, the view which has sometimes been suggested of its having been originally derived from volcanic ash, which was disseminated through the atmosphere and in falling supplied materials for a subsequently consolidated crust over the whole, or nearly the whole, of the then existing surface irrespective of contour and elevation. Subsequent denudation and erosion might easily have caused the break in continuity between the deposit at various elevations. In the hills between Sárgúja and Jashpur this original state of uniform covering has been better preserved than in any other part of India which I have visited. There, hills, slopes and valleys are to be seen alike covered by a coating of laterite. Supposing the whole country to have been submerged, and ferruginous deposits to have taken place, having the same nature and origin as bog iron ore, it can hardly be maintained that they would have accommodated themselves thus so strictly to the contours. At the same time, there are serious objections against the possibility of such a submergence having ever taken place. Had it been under the sea, the laterite could scarcely have failed to have contained marine organisms. On the other hand, its almost azoic character is in strict agreement with the view that its materials fell from the air.

Iron in laterite.

One objection which has been made to the probability of laterite having been so derived is the large percentage of iron which it contains; but this is capable of explanation. The thickest existing beds of laterite may represent much more considerable deposits of original ash from which the lighter portions have been removed and the iron has been concentrated by natural segregation. It is, I venture to think, easier to accept this as an explanation than that the underlying rocks of whatever character and however deficient in ferruginous constituents should have themselves contained the source of the iron which was released by their decomposition. In very many cases which I have examined, especially in the Mahánadi basin, the rocks underlying considerable beds of laterite show no sign of decomposition whatever.

The above is a somewhat different representation of the case from that which is so fully discussed by Mr. W. T. Blanford in the Manual of the Geology of India;[1] but the conclusions being in the main the independent result of observations made in Singhbhúm and the adjoining districts of Chutiá Nágpur and the Central Provinces, it seems not inappropriate to say so much on the subject here.

On the east of our present area the rocks become gradually covered up by the laterite, which in turn dips under the alluvium of Midnápur. Near the boundary there are several small hills of laterite, as Khari, H. S. 574, 12 miles east of Nársinghgarh.

Small laterite plateaus.

South of the Cháibásá road, near Kalkapur, there are a number of flat-topped hills, which, contrasting so strongly as they do with the peaked and sierra outlines of the ranges of trap and quartzite, must attract the attention of every traveller (*vide* Plate II). The heights of these hills are nearly uniform throughout, and probably do not exceed 150 feet above the plain. A great part of these small plateaus is formed of a considerable bed of laterite, the intervening portions of which have been denuded away. These caps of laterite rest indifferently on the metamorphic or sub-metamorphic rocks; occa-

[1] Vol. I., p. 365.

sionally a layer of broken and rounded rocks intervenes between the gneiss and the laterite.

It is difficult to estimate the exact thickness of the laterite, as in all cases the debris, fallen from above, has obscured the line of junction.

CHAPTER IV.

SUB-METAMORPHIC SERIES.

Section 1.—Area, Lithology, &c.

In the foregoing account of Mánbhúm the rocks of this series have been, in part, described. In Singhbhúm the main area occupied by them is reached, and some recapitulation of facts already mentioned will therefore become unavoidable.

Limestone and serpentine.

It may be said that there are to be found in this tract examples of almost every variety of sub-metamorphic or transition rocks which are known to occur ordinarily in other countries. Dr. E. Stœhr makes the same remark, but excepts limestone. Since his time, however, limestone has been found in several localities, where it occurs as a regular member of the sub-metamorphic series. True serpentine, which had not previously been discovered, has also been met with. Besides the many varieties of schists, shales, slates, and quartzites which make up the mass of this series, there are also some rocks which afford evidence of locally intensified metamorphism: these often have an excessively crystalline structure, and are not readily distinguishable from members of the older metamorphic series.

No outliers.

Throughout Singhbhúm, so far as it has been examined, the rocks of this series do not occur as detached outliers, but they surround isolated tracts occupied by the metamorphic rocks. One apparent exception does exist in the case of the wedge-shaped tract formed of slates and quartzites which lies in the centre of the principal metamorphic area; this, however, will probably prove to be in direct continuity with the main area of the sub-metamorphic rocks to the south.

Synclinal.

Viewed as a whole, the rocks of this series in the area included in the accompanying map, form a vast synclinal trough which on the north in Mánbhúm, is cut off by the great fault. At the base of this trough there appears to be another fault with which, as already stated on page 19, the occurrence of the Dalmá dyke is intimately connected.

Tilting and disturbance.

Although evidences of the existence of minor faults are rare, the beds show many signs of tilting and disturbance; these are probably chiefly due to the effects of the elevation of the insulated metamorphic areas, or, what amounts to much the same thing, to subsidence and sliding down of the beds on the surfaces of the older rocks with the lateral pressure resulting therefrom.

Outlines formed by subaërial denudation.

The dip or inclination of the beds impressed upon them by these causes is faithfully recorded in the ranges as they now appear which do not owe their existence to local elevations, but, as has already been stated, to the superior toughness or hardness of the rocks of which they are formed, the softer materials having yielded to the action of the ordinary sub-aërial denuding forces. Dr. Stœhr apparently held the opinion that individual peaks, such as Sideshar, were due to the elevatory effects of the trap-dykes which traverse the adjoining metamorphic area; but in this opinion I cannot concur. It is only on the south-eastern and south-western parts of that area that there is any evidence of the trap-dykes passing from the older to the newer rocks. On the north, on the other hand, there are numerous cases where the dykes are traceable up to the boundary where they abruptly disappear; and traces of them are in vain sought for in the sub-metamorphic rocks.

The general relations of the varieties of rocks composing the sub-metamorphic series having been discussed in the Mánbhúm report, and the distribution of the same not having been completely ascertained as regards the whole of Singhbhúm, it will be sufficient here, perhaps, to describe the characters and distribution of the several lithological varieties.

Section 2.—Quartzites.

To the hardness of the quartzites and the toughness of the schists, the preservation of the hill ranges there is mainly due. Not only have individual beds of quartzite themselves resisted the levelling effects of denudation, but they have, in many instances, protected the softer rocks in their immediate vicinity.

The Rangamatia hill station is formed of a quartzite in what appears to be a single bed; but south of the Kapargadi ghât it forms two distinct ranges between which there is one of trap which, however, has no connection with the trap of the metamorphic area above alluded to. It is possibly of contemporaneous origin, but in any case does not appear to have been instrumental in causing the inclination of the quartzites.

In the country to the north of the southern range or spur a gritty quartzite occurs associated with mica schists and interbedded traps. This rock is well seen in the Subarnarekha between Moholia and Belaipahari.

Close to the town of Cháibásá and also near Katigutu which lies north-east of the same place, there are some gritty quartzites or *arkose* beds not unlike some of the grits of Barakar age which occur occasionally at the bases of some of the coal measures.

Arkose grits.

At Katigutu these rocks strike from 30° north-of-west to 30° south-of-east, the dip being 25° to 30° east-of-north, and they are here closely associated with, and inseparable from, certain very Talchir-like mudstone shales which are undoubtedly referable to the sub-metamorphic series. It is strange that these rocks which show such slight evidence of metamorphism or even alteration should occur at or close to the base and resting on the oldest metamorphic rocks; while highly schistose or even gneissose beds should be found higher up in the series. The same phenomena have been observed in other countries. The cause is doubtless connected with that of the cases of excessive local metamorphism already referred to, and of which further mention will be made in subsequent pages.

Granulit.

To the west of Cháibásá, the sections reveal several varieties of quartzite of very similar character to those described in the Mánbhúm report. The principal of

these are a granular quartzite or granulit which forms the Soda hill south-west of Borkela and a blue vitreous quartzite seen in the valley between it and the Chitung hill.

Jasper beds.

In the river section at Cháibásá and at some other places, one being near the outcrop of a band of manganiferous iron ore south of the same place, thin beds of ribbon jasper occur, associated with mudstone shales and calcareous schists. Far to the south considerable thickness of these jaspideous quartzites are reported to exist, and the effect produced by the varied colours in the beds of the rivers is described as being very beautiful.

Another variety of quartzite rocks occurs associated with the copper-bearing schists. This occurs in thin beds which are often stained with a pea-green coloured chloritic mineral, and, sometimes, stains and encrustations of the copper carbonates are also to be seen upon them.

Conglomeratic quartzite.

At Amdiha between Saraikálá and Dugni there is a peculiar pebble bed; both pebbles and matrix consist almost entirely of quartz, and I was for some time doubtful whether to regard it as a conglomerate or a concretionary rock; the fact of a difference in colour and texture being occasionally apparent in the pebbles make me incline to the former supposition.

In Sargújá, in rocks of the same age, the occurrence of a very distinctly conglomeratic rock has already been recorded by me,[1] as also one in the older metamorphic rocks of Sambalpur.[2] In the former case the pebbles were of large size and were arranged with their major axes horizontal to the bedding.

Section 3.—Slates and Shales.

Although a considerable variety of slaty rocks occurs in Singhbhúm, I have seen nothing approaching to true roofing slate. Even where there is distinct cleavage structure, lamination is also present. Some of the laminated slates would doubtless answer for roofing purposes quite as well as the slates which are quarried in the Kharakpur hills; and being often of finer and more even texture, they can be, and sometimes are, used for making into writing slates.

[1] Rec., Geol. Surv., Vol. VI, p. 41.

[2] *Op. cit.*, Vol. X, p. 182.

Auriferous rocks.

A considerable thickness of grey and greenish mudstones and shales is exposed in the Sanjai river near Binj. The resemblance of these to the well-known Talchir shales is very striking. They dip at from 40° to 80° to north-west. Between the Sanjai and Cháibásá these rocks occupy a considerable area; they are there much crushed and jointed, and quartz veins occur in some abundance, though they are not of great length or size. It seems not improbable that they contain gold, as the superficial deposits are washed for gold during the rains by the inhabitants of Binj. The section of rocks seen in the stream near Kesia recalls some of those described in gold-producing countries.

Section 4.—Schists.

The schists of this series are, for the most part, distributed in definite zones, seldom occurring in regular alterations with other rocks. The principal of these zones forms the southern ridge of the northern range. It has already been described in the account of Mánbhúm. Some of the beds are talcose, in others there is a mixture of talc and mica, while the remainder are simply micaceous. The foreign minerals of commonest occurrence are andalusite, staurotite and magnetic iron. These are well seen in the rocks in the section at the Gutuhatu gorge at the foot of the Abunkapi Ghât.

Schists occur associated with quartzites and trap-like rocks in the country between Kharsawan and the Subarnarekha. These rocks afford an example of the higher metamorphism of beds comparatively high in the series which has been alluded to above.

In certain schists which form the northern flank of the central range, the copper ores, which will be described in the chapter on the economic resources, occur. The principal matrix is a black mica schist, with veins of quartz; but at Rájdoha there is a bluish grey schist in which copper-pyrites has been found. Of magnesian and chloritic schists there are two classes distinguished by their mode of occurrence, and possibly, too, by their origin. One is a regular member of the series, and is found with interbedded mica schists, quartzites, hornblendic rocks, &c., as the case may be, and the other occurs in very intimate connection

with the Dalmá trap, as has been already described in the Mánbhúm report. Both Dr. Voysey and Dr. Stœhr allude to the transition from the trap into the potstone.

No analyses are available from which it might be possible to indicate innate distinctions between the rocks of the two classes. Some differences in texture may however be pointed out. The trappean potstones generally, have either a fibrous or coarsely crystalline structure, while in those of the other class foliation may generally be discerned on close examination; but this difference in structure is possibly a secondary result produced by the influence of the trap which has thus obliterated the foliation.

The principal beds of magnesian schist are—

First.—In the southern ridge of the northern range or spur where it is associated with the above-described micaceous and talcose schists. Several mines and quarries particularly those of Tikri, north of Ghatsilla, are in this bed.

Second.—There is another bed which occurs in the southern range; it is worked at Dari and other points. It is remarkable for including veins of a white indurated silicate of magnesia.

Third.—There is another bed of potstone in the wedge-shaped area of sub-metamorphic rocks, which lies within the limits of the central metamorphic trap-traversed tract.

Fourth.—A short distance north of Jonuá, to the west of Cháibásá, there is an under-cut quarry in a magnesian schist, from which stone is extracted. It seems to be of less good quality than that obtainable elsewhere, having a very distinctly developed foliation structure.

The trappean potstones occur both within this area and in that described in the Mánbhúm report.

Serpentine.

In the Chitung hill, to the west of Cháibásá, there is a trappoid-looking rock, which, on examination, proved to be an impure serpentine.

Calcareous schists.

Highly calcareous schists occur at two principal localities, one being in the neighbourhood of Cháibásá and the other at Songra and Kondugutu, south of Bandgaon. In the

former locality the rock is a well foliated schist consisting of layers of talc and calc spur. This rock crops out close to *purana* Cháibásá on both sides of the village of Nemdih and at Kandoberá.

The other rock has a more crystalline structure; indeed it should scarcely be classed as a schist. Instead of talc it contains actinolite. It occurs in the Harni river near Songrá, and it is also seen near Lotá in Kondrugutu. There is still one more form of schist to be noticed; it is one of the component rocks of the Lopso range of hills but is apparently unrepresented elsewhere. It consists of tremolite, kyanite and talc in association with quartz. It weathers into large rounded masses which strew the ground at the base of the hills.

Section 5.—Hornblendic rocks.

Throughout the area included between the northern and central ranges there are frequent outcrops of hornblendic greenstone-like rocks which strike with the schists. As to the origin of these rocks, there is nothing to add to what has already been said in the Manbhum report.

Hornblendic rocks in other parts of the area, or in different horizons in the sections, are exceedingly rare.

CHAPTER V.

METAMORPHIC SERIES.

In the report on Mánbhúm it has been pointed out that there is a group of porphyric granites which are separable from the ordinary rocks of the metamorphic series by their lithological characters, and that these rocks occur exclusively in certain areas which are distinguished on the map. In Singhbhúm, there is no appearance of rocks presenting the same characters. But there are in this district two divisions or groups of the metamorphic series; one of these, the younger, consists of more or less schistose and gneissose rocks of the ordinary character, and which appear in certain places to blend off into the sub-metamorphic rocks, though elsewhere they seem to be distinctly separable. The other and older division to which in this area the term fundamental gneiss might be applied has so far as is known no very close analogue in this

region; but it seems to have many points in common with the gneiss of Bundelkhand which is considered to be the oldest in India. In both cases the principal variety is highly granitic with very obscure foliation, and besides other points of resemblance, both areas are traversed by a perfect net-work of trap-dykes. Mr. Medlicott[1] has pointed out further that the contact relations originally existing between the Central Singhbhum gneiss and the sub-metamorphic rocks finds a close parallel in the relations between the gneiss of Bundelkhand and the Bijaur or lower transition rocks of that area.

First, it will be necessary to describe the rocks of the younger division which may be regarded as being of the same age as the general metamorphic series occupying so large an area in Mánbhúm.

A limited tract of these rocks occurs to the north-west in the angle between the Subanarekha and the continuation westwards of the great Manbhum fault. This tract belongs to the District of Lohárdagá, but is included in the accompanying map. The rocks are fine quartzitic gneisses, alternating with felspathic and ordinary granitic gneisses; a few bands of hornblendic gneiss also occur, but trap is rare if it is not altogether wanting. An admirable section of these rocks is exposed in the river west of Mundrú. The strike is generally about 10° north of east, and the dip approximates to the vertical. Close to Jate the continuation of the fault is distinctly marked, and it is, as usual, accompanied by a run of pseudomorphic quartz. It is also well seen in the Tania river, 7 miles to the east of Mundru, where the pseudomorphic quartz, or fault-rock close by, at Muberá, forms a peaked hill. To the west of Jate the boundary has not yet been traced out, but it must in that direction be deflected southwards from its east-to-west direction as at the Perughag, a picturesque waterfall on the Karo river; the rocks are coarse granitic and porphyritic gneisses with a dip to the south-west of from 30° up to the vertical.

In the vicinity of Kharsáwán there is a small area of highly metamorphic rocks. From the character of some of the granites I should have been disposed to class them with the fundamental gneiss but for the

[1] Manual of Geology of India, Vol. I, p. 21.

fact that there are associated with them certain coarse schists in which copper ores occur. These copper deposits being on the same line of strike as those in the surrounding sub-metamorphic rocks suggested the possibility of this being an area of special local metamorphism, and the igneous-looking granite of the Akarsuni hill with which trap also occurs favoured this supposition; but in the description of the copper in the Economic Chapter below, another, and I think more probable, explanation is given which need not therefore be anticipated here.

A small inlier of metamorphic rocks is seen inside the sub-metamorphic boundary in the section exposed in the Karo river close to Cháibásá; it is almost too small to be represented on the map. Its occurrence is possibly connected with that of a north-to-south fault of the existence of which some evidence is to be seen in the surrounding schists and sandstones; but its full explanation remains to be ascertained in connection with the examination of the country further to the south.

To the north-east where the districts of Mánbhúm and Midnápur and Dhalbhúm meet, there is another inlier of metamorphic rocks. The portion of it included in Mánbhúm has already been described in the Mánbhúm report. Judging from the contortion shown in the ranges of hills formed of the surrounding sub-metamorphic rocks, this area is one of special upheaval. The hill ranges to the north and north-east of Ghatsilla indicate that the rocks forming them have been subjected to a considerable lateral thrust along their line of strike.

Outside the limits included in the accompanying map, but not far from the south-eastern extension of the copper-bearing zone, granitic gneisses are seen close to the Subanarekha. The relations of these have not yet been worked out. As marking a limit of the southern extension of the sub-metamorphic rocks, it may be mentioned that in Mohurbanj, at Mongol Pir Ghât, on the old Bombay road, granitic rocks occur.

Returning now to the central Singhbhúm area, the first tract of metamorphic rocks to be mentioned lies to the north and north-west of Cháibásá, and, as will be seen by reference to the map, has a triangular shape, the apex being near Amdá and the base in the hilly country north of Porahát. Its limits in that direction have not yet been

traced out. It is possible that a portion of these rocks belong to the older or fundamental group, as the sections seen in the Bamini and Bunjai rivers between Kerá and Chakardharpur and in the Bunjai at Koraikela show very granitic varieties; but towards the north-west no abrupt contacts with the sub-metamorphics are seen. The eastern end of the southern boundary is probably faulted, but to the west some indications of a transitional junction were observed in the Porahat hills.

Lastly, the metamorphic rocks of the central basin of Sargújá, for which the term fundamental gneiss has been suggested above, remain to be described. They exhibit but little variety in composition, and there is a total absence of the thin-bedded gneisses and schists which occur so frequently in the northern parts of Mánbhúm. The characteristic rock of this group is a coarse granite with no visible foliation. This rock forms huge bosses and tors the intervals between which are, for the most part, obscured by alluvium. The coarse porphyritic granitic gneiss which in Mánbhúm accompanies the former is not present here, and the granite veins or lodes, so common in the metamorphic rocks elsewhere, are seldom to be seen. The adventitious rocks of the series, if they may be so called, are syenites, quartzites, and magnesian schists. The granites vary considerably in texture and composition, the most common being a simple ternary granite with black mica.

Dr. Stœhr speaks of the influence of the vicinity of trap dykes being apparent in the superior development of the mica. Such cases must, however, be rare, as constant examination of junctions by me with the view of testing this statement has resulted in the discovery of pegmatitic granites, or of rocks in which the component minerals had become more or less fused up together, rather than of rocks in which any remarkable increase in the size of the crystals of mica was apparent. The syenites pass insensibly through hornblendic into simple mica granites. At intervals throughout the rocks of this series there occur quartzites, the true relations of which to the rocks which surround them it is exceedingly difficult to determine. They generally form small hills, beyond the limits of which they cannot be traced. But two alternatives can be put forward to explain their occurrence, either they occur as lenticular

bands in the gneiss dying out within short distances, or they are outliers of the sub-metamorphics. Possibly both explanations may be required to account for different cases, but in the absence of positive proof to the contrary, I am inclined to believe that the quartzites forming the small hills near Potká, in Dhalbhúm, may perhaps be regarded as belonging to the sub-metamorphics.

Magnesian Schists.

The magnesian schists occur in several places associated with the granites. Differing in no respects, so far as their external appearance is concerned, from those which belong to the sub-metamorphic series, their presence often gives rise to some difficulty. These magnesian schists occur with the granitic gneisses 2 to 3 miles east of Chaibassa and in other places.

This principal area of granitic rocks embraces, so far as its boundaries have at present been determined (*i.e.*, on all sides except the south), an extent of 450 square miles. The general aspect of this area may be best seen from the summit of Bhagmúndi hill. A wide plain bounded on the north and east by the well-marked ridges of sub-metamorphic rocks stretches before the eye. Crossing this plain in four or five different series are numerous trap dykes, the effect produced by the intersections of which has been, not inaptly compared to a chess-board (see Plate II).

Even at the elevation and distance of Bhagmúndi the few small hills of granite, whether they stand isolated and distinct, or are embraced in the angle between two intersecting dykes, may readily be distinguished from those consisting of trap.

As a rule, in the intervals between the dykes the rocks are obscured and covered up by alluvium. An occasional outcrop of the granitic gneiss in a stream or on the flank of the trap, where the hardening to which it has been subjected has given it the power of resisting for a longer period the destructive influence of denudation, alone serve to indicate the nature of the rock beneath. From the manner in which the schists and quartzites cloak round this area dipping from it at high angles, the conviction that it is one of elevation is irresistible. This point, however, has already been discussed in the description of the sub-metamorphic rocks.

Through the centre of this area runs a wedge-shaped range of sub-metamorphic hills in a very singular manner; the rocks composing it appear to die out towards the north a little beyond the Midnápur and Cháibásá road. The only explanation that can be offered to account for their peculiar position and preservation is that they were caught up in a fold of the granites and let down by a fault on the western side; on the eastern, the boundary appears to be perfectly natural. A very clear section is exposed near the Galusingi hill.

Tracing the *junction* of the two formations round the whole area, it is found that the rocks of the sub-metamorphic series in contact with the granites vary considerably. At a few points the evidence of the existence of local faults is very strong, but it is evident that the greater part of the boundary is natural. Commencing to trace the boundary round by north and north-east from Cháibásá, we find some bluish grey sandstones close to the cutcherry resting upon the granite. Less than a mile north of the station the boundary turns to east, and the lowest rock is a kind of coarse grit. After pursuing that direction for about a mile, the boundary then strikes north-north-east till it meets the Raro river when it again turns to east. The rocks at this point are mudstones and are seen resting immediately on the rough and weathered surface of the granitic gneiss. Leaving the Raro, the boundary now strikes northwards for about 6 miles cutting across a loop of the Korkai in its course; at the point where it crosses the river near Tolko it is evidently faulted.

Sweeping round Saráikálá, it again strikes the river about 2 miles east of that town. The section in the Korkai at Saráikálá is singularly fine; huge outcrops of several varieties of granite gneiss rocks strike across the river, which is nearly a quarter of a mile wide. Trap-dykes abound both in the bed of the river and in the country to the south.

Leaving Saráikálá, the boundary, well marked by a ridge of shales resting on gneiss, is soon met with crossing the road, a short distance below which it strikes the river, as has already been mentioned.

Thence eastward it pursues an irregular course the character of which may be best understood by reference to the map. In the Garhá river

the junction is well seen; thence the boundary runs along at the foot of the Rangamatia range, and crosses the road a short distance from the entrance to the Kapargadi Ghát. Again it ranges along at the foot of the hills for about 8 miles further, after which it becomes deflected to the west where its precise position becomes a matter of great uncertainty owing to the presence of a number of laterite-capped hills and of the tendency which the trap here exhibits of passing from one formation to the other; this latter cause of difficulty is especially apparent in the vicinity of Mandpur.

CHAPTER VI.

IGNEOUS ROCKS.

Section I.—Trap of the Sub-metamorphic Area.

The great Dulmá trap-dyke which has been described in the account of Mánbhúm was during the examination of Singhbhúm followed in both its eastern and western extensions. On the west, south of Tamar and north of Kenke, it suddenly increases in width; this appears to a certain extent to be due to a doubling back on itself. Still further to the west it rapidly diminishes to a width of about one and a half miles. Thence it was traced into the plateau as far as Jatoberá south of Bangáon. Owing to its intimate association with greenish schistose rocks, it is often difficult to trace satisfactorily the precise position of its boundaries.

In some places, as for example on the road between Hedingdá and Rabo, this trap exhibits a sort of pseudo bedding; but the rock is nevertheless, throughout, a *bonâ fide* intrusive trap, and is not unfrequently vesicular. The highest hills in Singhbhúm which range from 2,500 to 3,000 feet are all situated on this band of trap. In its eastern extension, though traceable for some distance, it ultimately becomes lost in the crushed and distorted strata of Midnápur.

To the west of Cháibásá and north of Borkela, there is a group of hills formed of a very dense trap, similar in character to portions of the Dulmá dyke and probably having a similar origin. Dipping away from

it there are shales and schists which appear to have sustained some local metamorphism. Unlike the Dulmá outburst, which in some parts of its course runs with the strike of the rocks and is continuous for many miles, that at present under notice which may be distinguished by the name of the principal peak, as the Ongabirá trap, occupies a very irregular area the limits of which may be best understood by a reference to the map.

Section II.—Trap of the Metamorphic area.

The existence of a complicated net-work of trap-dykes traversing the granitic rocks of the principal metamorphic area has already been alluded to. This trap, speaking generally, is a coarsely crystalline diorite, but local modifications are not uncommon. In some places it is a compact, homogeneous greenstone or aphanite. Weathering often produces a white crust which prevents the rock being identified from a distance as its spherical structure and other characters would otherwise enable it to be.

For convenience the dykes may be classified as belonging to one or other of the following *series* :—

North to South.
North 30° east to south 30° west.
North 40° west to south 40° east.
East to west.

Departures from these directions to the extent of 5° and sometimes 10° occasionally take place. While alluding to the bearings of the dykes, it may be mentioned that the trap is frequently so rich in magnetic iron that the compass becomes useless.

The heights of a considerable proportion of the dykes above the plain are from 50 to 100 feet, but some of the principal are much higher. These at frequent intervals have peaks rising from 200 to 400 feet above the plain, such as Pintla 841 feet; Paorú 953 feet; Banduá 980 feet, Lodhá 1,175 feet. Besides these, there are two upwards of 1,000 feet above the plain, namely, Chauriá (No. 1 H.T.) 1,758 and Bhagmurí 1,997 feet.

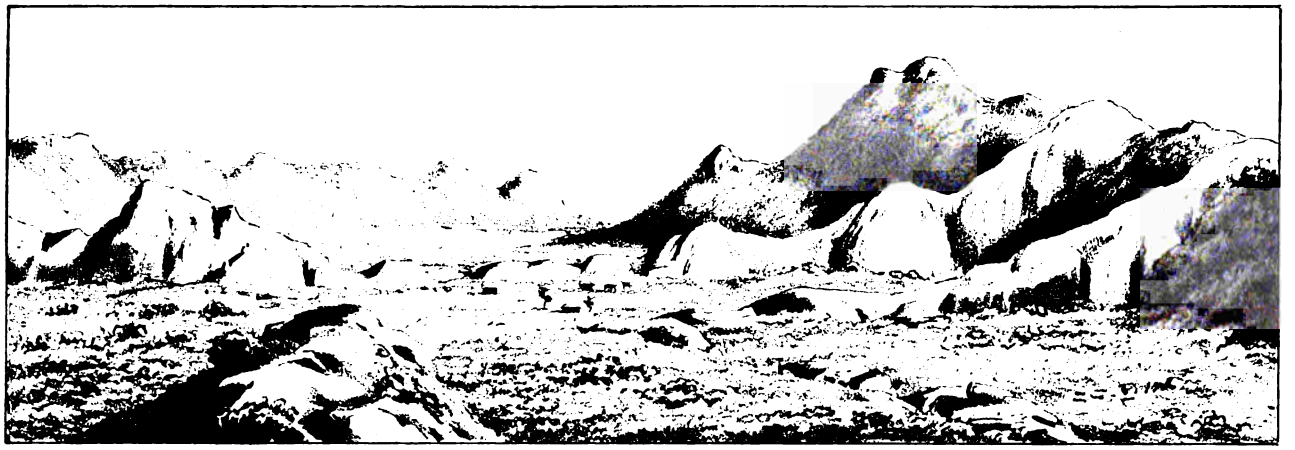
The intersection of the dykes belonging to the several series produces a very peculiar appearance, which has been aptly compared by Dr. Stœhr to a chess-board. Some idea of it may be gathered from the illustration on Plate II.

I was not able to make out any order of succession in the production of the different series of dykes. An examination of many intersections led rather to the conclusion that they were all of synchronous origin. From one aspect, one would seem to penetrate the other; but on moving the position of observation to some other point, the relations would seem to be reversed. Each seemed to have communicated its own outline to the other.

The usual tendency of most traps to weather into more or less spherical masses is well seen. But on the crests of the ridges and the tops of the peaks the rock is much jointed and split the intersections of several plains of jointing, which occur in both vertical and horizontal directions, resulting in the production of a number of irregular prisms. These prisms have been regarded by some observers as corresponding to the columns of basalt, but with them they have only a remote connection. There is no limit to the number of their faces, and consequently none to the angles which are between them. The most probable supposition is that the joints are simply due to contraction on the original cooling of the mass. Some of the joints, under the influence of weathering and the removal of lateral support, have gaped to the extent of 18 inches or 2 feet; between this and absolute junction of the opposite faces there is every intermediate condition of approximation to be found.

Some of the previous observers in this district hold the opinion that the splitting is due to another cause.

Colonel Haughton says:—"The rock of this hill (Bhagmundí) shows "a disposition to a columnar form. I was much puzzled to account for "the sharp angular appearance which the rocks forming the surface of "these hills exhibit, the more so as in many instances the fracture was "recent. Careful observation showed that these hard masses had split of "themselves by the unequal contraction of their parts, when, after being "heated by the sun, they were suddenly cooled by heavy rain."



INTERSECTION OF TRAP DYKES NEAR CHAURIA HILL.

J. Schaumburg Lith:

QUARTZITE & TRAP RANGES WITH LATERITE PLATEAUS AT BASE AS SEEN FROM POTKA.

Dr. Stœhr writes:—"This very hornblendic diorite has a remarkable "tendency to spheroidal structure, and appears on the summit split into "vertical columns like ruined castles. It is noteworthy that one often "finds such clefts with quite fresh surfaces of fracture; this is the result "of the sudden cooling by rain of the rocks when highly heated by the "sun's rays, as I determined by direct experiment."

Were it not that the phenomena which I have observed are of such an extensive nature that for their production the causes suggested are obviously inefficient, I should have the greatest hesitation in disputing an opinion so strongly and apparently conclusively put forward. It is to be regretted that Dr. Stœhr does not record the details of his experiment which one might reasonably expect on so important a point.

I endeavoured to give the matter a fair test, and accordingly poured a quantity of cold water on the rocks of the tops of Bhagmundi hill which had been subject to the rays of an April sun up till about 3 P.M. So far as I could see, it was entirely without effect. If the opinions of Colonel Haughton and Dr. Stœhr be correct, the conditions were so favourable, that at least a visible crack should have been produced.

There are two objections to the theory which I believe to be insurmountable.

1. The immense extent of the cracks which penetrate in many cases to unknown depths.
2. The existence of horizontal cracks in positions fully protected from the influence of sun and rain.

That the sudden contraction of a few inches in depth of rock, which is the utmost that could be effected by heat or cold, could produce a cleft extending to a depth of, say, 30 to 100 feet, is difficult to believe.

On the south-east of the metamorphic area, as already mentioned, there are cases of the dykes passing from one formation into the other. The principal are the Kálkápur dyke, which runs into the sub-metamorphic rocks near Mandpur, and the dyke which forms Bhagmundi hill, crossing the junction of the two formations near Tangra. In the northern half of the area, I was unable to discover a single instance of trap passing out of the metamorphic into the sub-metamorphic rocks.

At Gopínáthpur there is the only instance of anything like a focus to the trap. From a small group of trap hills, covering an area not far short of 1 square mile, dykes strike out in all directions.

Singularly, it is only in this one metamorphic area of all those which have been above enumerated that there is a development of trap worthy of particular notice. In the Chakardháp̣ur area one dyke occurs close to Koraikelá, and there is another which crosses the boundary of the two formations at Potoberá.

In the Kharsáwán area there are traps running with the strike.

CHAPTER VII.

ECONOMIC RESOURCES.

Gold, Copper, Iron, Manganese, Lime, Potstones, Building Stones, Slate.

GOLD.—In Singhbhúm gold occurs in very much the same manner as it does in Mánbhúm, the principal gold-bearing rocks being in unbroken connection throughout and forming one united tract, with this difference, that in central Singhbhúm, so far as is certainly known, the sub-metamorphic rocks alone contain gold.

In Mánbhúm quartz reefs are not abundant in the sub-metamorphic rocks, and the washings seemed to point to the magnesian schists and certain bluish quartzites as being the sources of the gold. In Singhbhúm, especially to the north and west of Cháibásá, quartz reefs are abundant in some earthy shales and slates, though not continuous for long distances, and it seems probable that they may prove to contain gold. The only nugget seen by the writer in Singhbhúm was in a quartz matrix; and gold, but only in small quantities, is said to have been obtained by quartz-crushing at Landú.

Before giving the known details regarding these localities, it may be well to describe the gold-washers and their operations, it being understood that they apply equally to those of Mánbhúm.

The class who more particularly follows the trade of gold-washing belong to a tribe of Gonds, known as Jhorás, Dhorás, Dokrás, Torás,

Kumulpoor
Puracha
Tentoolia
Mullegee
Nawadihee
Benagurreah
Nipaneeah
Champasole
Amelharee

or Jhárás, according to locality. The name Jhorá is said to be derived from *jhori*, a small stream; but Dhorá may be derived from *dhoná*, to wash. In the case of these people, both sexes engage in the pursuit; but the Ghásis, a local tribe of unknown origin, also occasionally wash for gold, among them the men only, while among certain Kol or Mundá tribes to the west of Singhbhúm the women, wash for gold; but their male relatives regard the work as an unworthy occupation for their sex.

The methods employed by these different tribes appear to be identical in all essentials. Each occupies a distinct tract, and poaching on each other's favourite streams is not indulged in to any great extent.

The wooden dish used for washing by the Jhorás measures on an average about 28 by 18 inches for the men, smaller ones being used by the women and children. The dish is hollowed somewhat eccentrically to a maximum depth of 2½ inches. A scraper formed of a flattened iron hook, set in a handle, serves to collect the auriferous sand and gravel which accumulates in the angles formed by the rocks in the beds.

The dish when filled is placed in shallow water, and the operator, working with his hands, soon separates and throws aside all the coarser gravel and stones, while the agitation of the water serves to carry away all the mud and lighter portions. The dish is then balanced on the palm of the left hand and oscillated to and fro with the right; this serves to throw off the greater portion of the remaining gravel, and the process is completed by a circular motion which is communicated to the water in the hollow of the dish, by which even the smallest particles of foreign matter are separated, and the final result is a residue of black iron sand in which specks of gold are readily apparent; but as mercury is not employed in this part of the country, all the very small and invisible gold is lost.

The daily earnings of the gold-washers are small, but might, no doubt, be increased, if it were not that they are always satisfied when enough gold has been found for procuring the day's subsistence.

Colonel Haughton says:—"The Ghásis can always reckon on earning from three to four pice per day, and I am assured that a vigorous man often gets as much as twelve annas, which, as the ordinary rate of field

labour is about one pice, must be considered a very large sum."[1] Mr. Robinson found in a trial which he made at Rohobe, in Udipur, that men to whom he paid one anna could produce for him from three to four annas worth of gold. Colonel Dalton states that the washers themselves regard it as a very poor trade, simply yielding, they say, *pét bhur* (bellyful). Dr. Stœhr, in his paper on Singhbhum, states that he found the average daily earning to be about 25 centimes (rather more than an anna and a half). The men whom I met with stated that they could earn about an anna a day, and occasionally three or four annas.

The principal places where gold has been found in Singhbhúm are as follows:—

Kamerárá.—Lat. 22° 15′. Long. 86° 43′ 30.″—According to Colonel Haughton, gold has been found in the bed of the Subarnarekha at this locality which is on the eastern margin of the rocky tract. He states his belief that the sands of this river continue to contain gold from thence to the sea.

Kapargadi Ghat.—Lat. 22° 39′. Long. 86° 23′.—A nugget of gold shown to the writer when in Singhbhum was said to have been found close to the pass on the Midnapur road through the Kapargadi Hills.

Landú.—Lat. 22° 43′ 30″. Long. 86° 15′.—At Landú and various other places the copper ores were in some cases found to be slightly auriferous. A Mr. Emerson was employed by the Singhbhúm Copper Company specially to investigate the gold resources of the country. He is said to have crushed a quantity of quartz, but there is no record as to the results which he obtained.

Asantoriá.—Lat. 22° 44′. Long. 85° 51′.—At Asantoriá or Assuntulleá, gold is said by Colonel Haughton to occur *in situ;* but it appears from the context that it is not to be understood that it was actually found in the rock there; but the locality being higher than the neighbourhood, it was concluded that the matrix was close by.

Sonápet.—Lat. 22° 53′. Long. 85° 44′ 30″.—Sonápet or the 'mother of gold' is the valley of the Sonai river to the north-west of

[1] Jour., As. Soc., Bengal, Vol. XXIII, p. 110.

Kharsawan; all writers on the district refer to it as containing more gold than other parts of the district. Some years before 1854, nuggets were found there according to Colonel Haughton,[1] but the finder never divulged the secret of the exact spot.

Porahat.—Lat. 22° 36′. Long. 85° 30′.—Colonel Haughton alludes to a tradition of a regular gold mine having been driven into the side of a hill in the jungles of Porahat. No traces of this mine remain at present. Gold-washing is carried on in the streams of Porâhât by the women only of the Mundâ inhabitants. Dr. Hayes, late Deputy Commissioner of Singhbhûm, says that the washers make use of an infusion of the leaves of the *Atungi* tree to separate the gold from the sand. I have not been able to identify this tree.

Sarandâ.—In Sarandâ, which is a hilly elevated tract included in Singhbhûm, and which intervenes between Singhbhûm and Gangpur, gold is washed for to some extent. Its occurrence in Anandapur and at Arabhangâ is recorded by Colonel Haughton.[2] The latter name does not appear on the map, but close to Dhipa gold-washing was witnessed by the writer.

Dhipâ.—Lat. 22° 26′.—Long. 86° 15′.—The bed of the Koel near Dhipâ yields a small amount of gold. The 'pay-dirt' was scraped out from the nooks and crevices of some protruding rocks. Both sub-metamorphic and metamorphic rocks occur in this region. Colonel Haughton on his map represents the beds of the Koel, Karo, and Sunk, and the Brahmini, which is formed by the junction of the three as gold-bearing, and they are so no doubt to some extent.

Copper.—The district of Singhbhûm and the state of Dhalbhûm include within their limits the mostly widely extended copper deposits at present kown to exist in India. Traces of copper ores, often principally marked by old excavations, are found over a distance of 76 miles or from the neighbourhood of Lopso on the frontiers of Lohârdagâ to Kamerârâ on those of Midnâpur. This deposit appears to exist on a well-defined horizon of the sub-metamorphic or transition rocks and close

[1] *l. c.*, p. 111. [2] *l. c.*, p. 107.

to their base, and it seems to be not improbable that it is represented to the north in Mánbhúm by the similar rocks which include copper ores close to and on the line of faulted junction between the sub-metamorphic and metamorphic rocks of that district.

As a rule, the copper ores occur disseminated through the schists and the underlie of the deposit, where massive, in general corresponds to that of the including rocks; but in some places the ores appear to be distributed in lodes, and the only safe conclusion to be drawn is, that, as in some other parts of the world, there is a two-fold mode of occurrence, the lodes being of secondary origin, and having been formed by segregation in fissures and fractures produced on the upheaval of the beds. If this be the true view, then the copper ores were originally deposited either mechanically or chemically at the same time as the other materials, and they were all together subjected to metamorphic action. Although it has been above said that the ore occurs in a zone in the sub-metamorphic rocks, there is one important exception which must not be overlooked. On the same general line of strike the character of the rocks is locally interrupted in the neighbourhood of Kharsáwán, where occupying a small area rocks are found, which are lithologically undistinguishable from those of the older crystalline formation; and here the copper ores also occur. These relations will be clearly seen by reference to the map. At first, supposing these rocks to really belong to the older formation, the conclusion might be drawn that the ores must necessarily occur in lodes, coming from the deep throughout; but on the other hand, if the possibility of a secondary formation of lodes be granted then, by percolation from above, these ores may have been deposited in fissures in the deeper rocks which were at one time, no doubt, covered over by the younger copper-bearing strata. This explanation appears now a more satisfactory one to me than that which I originally suggested, namely, that these gneissose and crystalline rocks of Kharsáwán might merely owe their characters to excessive local metamorphism and were not really older than the less crystalline rocks of the sub-metamorphic series.

The accounts of these deposits published in the Records of the Geo-

logical Survey,[1] which give all the available information at upwards of 30 localities, are therefore readily accessible to the public, it will be unnecessary to repeat the details here. Presuming, therefore, that those who are likely to be interested in the subject will refer to the more complete descriptions, a few general remarks will suffice to dispose of the matter in this volume.

Indications exist of mining and smelting having been carried on in this region from a very early period; and the evidence available points to the Seraks or lay Jains as being the persons who perhaps 2,000 year ago initiated the mining.[2] The number and extent of the ancient workings testify to the assiduity with which every sign of the presence of ore was discovered by these early pioneers and those who followed them up to recent times. The first published notice of the presence of copper ores in this area was by Mr. Jones in 1833.[3] In 1854, Captain, now Colonel, J. C. Haughton[4] published a description of the mines, and in the same year they were visited and reported on by Mr. Ricketts.[5] Under the auspices of two Calcutta firms Mr. Stœhr came out to India soon after; and on his report a company was formed in 1857, mining commenced at Landú and Jamjúrá, and from 1,200 to 1,300 cwts. of fine ore was turned out monthly. A heavy royalty of Rs. 9,200 yearly to the Rájás of Saráikálá and Dhalbhúm, an expensive establishment of Saxon miners and English smelters, the erection of a costly foundry and engine, and other premature and excessive expenditure led to the dissolution of the company in 1859. In 1862, an effort was made to start another company with a capital of £120,000; but by 1864 its operations ceased. According to the prospectus of this second company, the royalty was fixed at half the previous amount.

[1] Vol. III, p. 86, namely, abstracts and translations of papers by Dr. E. Stœhr, Virtel. der Nat. Gesell. Zurich, 1860, Vol. V, p. 329, and Neues Jahrbuch fur Min. Geo. Pal. for 1864. Also report by V. Ball, with a map of the localities.

[2] *Vide* Proc., As. Soc., Bengal, June 1869, p. 170.

[3] Asiatic Researches, Vol. XVIII, p. 170.

[4] Jour., As. Soc., Bengal, Vol. XXIII, p. 103, with map. In substance reproduced in a report by Mr. Durschmidt, published in 1857.

[5] Sel. Rec., Bengal Govt., XVI, p. 77.

Numerous assays of the ores have been made, and these will be found in the papers first quoted; but the really important question was not definitely settled by the operations of either of the companies. It is as to the abundance of the ores. Good ore was met with at many points, yielding a high percentage of copper; but in most cases the unusual richness proved to be local and confined to pockets and unremunerative copper-permeated schist was found further to the deep.

Copper pyrites was first struck by the second company at Rajdoha just before operations ceased. All the ores previously obtained had consisted of the carbonates and oxides.

Traces of silver were found in some of the samples which were assayed, but not in all. A very small percentage of the precious metals sometimes enables inferior copper ores as at Eisleben in Prussian Saxony to be worked with profit, though the actual manufacture of the copper may itself be carried on at a loss.

Should the proposed line of railway to the Central Provinces traverse Singhbhum, this copper deposit may yet prove of value, the accessibility to Calcutta being by that means so greatly increased.

Iron ores.—Although iron ores are perhaps not so abundant nor so widely distributed in Singhbhum as they are in Mánbhúm, there are still several localities where large supplies of good ore could be obtained.

A large proportion of the ore which is used in the district is derived from ferruginous schists; but from these no considerable supply could be obtained. As in Mánbhúm, nests of very pure hæmatite ores occur in the trap of the Dulmá dyke, the finest example being in the river near Songrá. In the eastern parts of the district the laterite ores are sometimes manufactured into iron.

By far the most promising source of iron ores, however, is to be found in a number of lodes or veins which occur in the sub-metamorphic rocks in the neighbourhood of, and to the west of, the town of Cháibásá, the only fear about them being that in practice they might be found somewhat too silicious. Many of them, however, give great promise of being rich in manganese. There is one well-marked ridge of this mangani-

ferous ore mixed with vein quartz south of Cháibásá and east-north-east of Puráná Cháibásá. It strikes to north-north-east, south-south-west, and in places north and south, or with the bedding, the rocks being jaspidious and saccharine quartzites. A somewhat similar outcrop of ore is seen east of Cháibásá.

Close to the Chitung hill to the west of Cháibásá there is an outcrop of a very rich-looking brown hæmatite; and in the village of Jogidárú there are ten families of kumars and about the same number of furnaces. The ore for these furnaces is obtained close to the village to the north. Near Lajiá the surface is strewn with ore from broken outcrops; some of it is rich in manganese.

South of Saitbá, towards Jogohatú and Changijari, iron ores on at least three distinct runs are very abundant. These strike with the bedded rocks from 30° north-of-east to 30° south-of-west. The dip is nearly vertical. Beyond Baijoro in the direction of Tendú, iron ores are again abundant, and here too a proportion of them contain manganese.

MANGANESE.—From what has been said of the abundance of manganiferous iron ores, it will be seen that there is a fair prospect of the neighbourhood of Cháibásá yielding a good supply of manganese which will be of value should iron manufacture ever be recommended on a large scale in the Rániganj coal-field. If the line of railway to the Central Provinces should pass close to Cháibásá, as it is to be hoped it may, a material suitable for the manufacture of *spiegel eisen* which might otherwise have to be imported would become available at a comparatively small cost. The use of *spiegel eisen* being an essential part of the Bessemer conversion process, it is obvious that a manganiferous ore at an accessible locality has a special importance.

LIME.—There are several sources of lime in Singhbhum.

1. The ordinary Gutin or Kunkar.—This occurs in the usual manner; it is found in both the metamorphic and sub-metamorphic areas, but I think more abundantly in the former.

2. Bedded Gutin.—In Cháibásá a bed of this occurs in the bank of the river. It is used in the manufacture of lime. It is said to contain

fragments of bones. This may be due to some fancied resemblance to bone which the nodules assume. None were to be seen when I was there.

3. Tufa.—On the top of the quartzite range north of the village of Bansiderá there is a deposit of tufa crusting over the quartzite. It is penetrated by a net-work of tubes which are no doubt due to the decay of twigs which were in the first instance caught up and surrounded by the calcareous matter. The supply of this is limited.

4. Calcareous Schists.—Such is the amount of impurity in these rocks that it is doubtful whether they would yield a useful lime. The crucial test has not yet been applied, so far as I know. Of the two, I should say that the talc in the Cháibásá rock would be less likely to interfere with the burning and subsequent use of the lime than the actinolite which occurs in the schists of the Harni river near Songra and at Lota in Kondugutu.

POTSTONE.—The principal places where potstones occur and have been worked are the following :—

Dari, south of Landú.
Belaipahári.
Tikri.
Mutiágará and Sideshár.
Tilaijhor.
Palákuchá.
Domápal (in the Subanarekha).
Koraikelá.

Dari.—Potstone occurs in the Dari hill in distinct *beds*, with a dip of 30 to north. Shafts are numerous; they are generally about 20 to 30 feet deep; from the bottom galleries spread in different directions; so soon as the rubbish becomes troublesome they are deserted. The stone is so easily worked that a shaft 3 or 4 feet deep and about the same in diameter can be sunk in as many days by a single man.

Here the story was the same, as at all similar localities the famine had carried away the majority of the workers. In the year 1869 only fifteen or sixteen men were engaged in the mines and manufacture of plates.

The articles are roughly cut in the hills and then finished off by means of lathes in the villages. The mahájans pay the manufacturers at the rate of five or six peiss for each plate or bowl.

The Rájá is said to receive Rs. 80 in kind for granting the privilege to work these quarries and mines.

Belaipahári.—At this place there are some very extensive old workings, many of the huge open shafts being 50 feet deep; from these, galleries strike out all round. There were said to be 60 men, chiefly of the Bhumiz tribe, engaged. The *salammi* paid to the Rajah amounts to about Rs. 150 per annum.

Tikri.—Close to Tikri, there are said to be about 100 more or less extensive mines.

In 1869, only five were worked by the same number of mahájans who remained on the spot to look after their interests. These men told me that each plate passes through about four hands.

1.	The man who quarries earns	4 peiss ?
2.	„ „ rough shapes	1 „
3.	„ „ clean „	1 „
4.	„ „ „ turns in lathe	1 „
		1¼ annas

The mahájans get from 10 to 12 peiss each for them. All this is their own statement and is possibly not quite reliable; they seem to be well to do, and would scarcely remain almost exiles in these hills away from their own people, unless they found it very profitable to do so.

Before the famine there were 10 mahájans; in 1869 only 5. The others had to stop their mines from want of labour. There were said to be about 60 men employed at Tikri. Work is only carried on in the cold and hot seasons. The mines are deserted so soon as they become partially filled with water, as it is cheaper, they say, to open up new ones than to drain the old. The mahájans told me they paid a *salammi* of Rs. 41 to the Rajah.

The other localities above mentioned are not now regularly worked, but ancient pits and shafts abound.

BUILDING STONES.—Little need be said on this subject, as the rocks are of characters well known. In the hill ranges between Mánbhúm and Singbhúm, the granulit or felspathic quartzite, which has been described, would very possibly yield a material equal to the Bardwán paving stone of the Susuniá hill.

Ancient buildings, from which a conclusion might be drawn as to the relative lasting power of different building stones, are almost, if not wholly, absent from Singhbhúm.

SLATES.—In the course of the preceding pages, the flaggy laminated slates of the sub-metamorphic rocks have been alluded to. I do not think it at all improbable that slates equal to, possibly better, than those of Kharakpur could be obtained at many localities in Singbhúm. The fact that slates suitable for school purposes are obtained has also been above stated.

Note on the proposed Railway.

On the accompanying map, the route which a proposed line of railway connecting Calcutta with the Central Provinces would take has been laid down in so far as it refers to the districts of Mánbhúm and Singhbhúm.

The advantages which this line possesses over some others which have been proposed, especially as regards facility of construction, have been fully set forth in a memorandum which has lately been printed by the Bengal Government.

The line from Barakar to Sambalpur *viá* Porahat would be about 278 miles long, and would nowhere rise to a greater elevation than about 950 feet above the sea. It would start from the Raniganj coal-field and reach the Raigarh and Hingir coal-field in the neighbourhood of Sambalpur. It would possibly lead to the development of some of the metalliferous deposits of Singhbhúm, and it would facilitate communications between Western Bengal and Cuttack and the coastal districts of Madras by a branch line down the valley of the Máhánadi which would cross the Talchir coal-field. Besides all this the main object, that of tapping the rich tracts of Chatisgarh, would be effectively accomplished.

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THE GEOLOGY OF THE PRÁNHITA-GODÁVARI VALLEY. *By* WILLIAM KING, B.A., *Deputy Superintendent (Madras), Geological Survey of India.*

PART I.

CHAPTER I.—GENERAL DESCRIPTION.

Introductory.—The Godávari river for a considerable length of its lower course traverses a great area of Gondwána rocks, which connects the Nágpúr, or Kámthi, and Chánda fields of these with the coastal patch of the same great formation on the Coromandel in the Godávari district of the Madras Presidency. The Chánda rocks extend southward by the Wardha river valley and so with the Pránhita river to its junction with the Godávari, whence they are continued down the valley of the latter river; and it is mainly on this system of river basins that all the formations treated of in this memoir occur, an area which may be very conveniently described under the name of the Pránhita-Godávari valley.

The term Pránhita-Godávari.

It was in the following out of this great series of the plant-bearing sandstones with the economically interesting coal-measures of their Damúda subdivision that this immense tract of wild and poorly explored country came to be visited by the Survey; and these rocks, as having engaged most of our attention, will necessarily receive the greater consideration now, but the several other formations will, as far as they have been studied, receive due notice.

A region of Gondwána rocks.

The general run of the Godávari.

The Godávari rises, as is well known, at Nassik, far up in the Deccan, among beds and flows of the great Deccan series of volcanic rocks, in which it follows an east-south-east direction for nearly two and a half degrees of longitude, when it breaks ground in the gneiss country of Hyderabad, traversing this for nearly a degree further in the same direction, and from which it passes by an occasionally more restricted channel to the country and the rocks about to be described. Still in the same direction, but with, now, some sharp bends, it keeps on for about forty miles, when it is joined by the Pránhita at Káleswar[1] a few miles below the civil station of Sironcha. So far the river has been following or pursuing a generally east-south-east or east-by-south course; but after the confluence at Káleswar, it gradually trends to the south-south-east, and so continues for over a hundred miles, when it again turns eastward, and passes by its great gorge or defile through the Pápakonda range of hills—known otherwise as a portion of the Eastern Ghâts—to the low country of the Coromandel, and its delta at Dowlaishweram below Rájahmundry.

Position and extent of the field.

The Pránhita-Godávari area is thus a narrow strip of Peninsular India, extending from about Dhába, or Porsa on the Wardha, in a south-south-east direction to Chintálpudi, some forty miles north of Ellore in the Godávari district. It is about one hundred and ninety miles long and sixty-five miles broad, giving an area of, roughly speaking, about twelve thousand square miles.

Rocks strike with the field.

With the exception of the bottom or floor rocks, namely, the gneiss or crystalline series which extends far to the eastward and westward of the colored area laid down in the accompanying map, all the other formations occur as outcrops or bands roughly parallel with the longest side of this strip of country; and they, as well as the gneiss, have their strike also generally in this direction.

[1] Marked wrongly as Kaleser on my map, it ought to be Káleswar, and will be found so spelt throughout this memoir. I must apologize for a large percentage of errors in this way in the map, also for many omissions of important villages. I have, however, tried to make up for these by corrections in foot-notes.

Drainage system.—The main artery of the drainage system is the Godávari, fed in this tract by its more important tributaries—the Manér, Pránhita, Indrávati, Pángadi Vágu, Tál, Kinersáni, and Sáveri or Sápri. The Pránhita is the most important feeder, though a very short run—some sixty-five miles—of its course goes by this name, it being at that distance north of its junction with the Godávari, formed by the confluence of the Wardha and Wain or Waingunga, two large rivers themselves, which, with the Pránhita, drain an area nearly as large as the Godávari above Káleswar. An important tributary of the Pránhita in connection with the rock formations, is that coming from the westward past the large village of Jánagaom or Jángaom, and joining the river at Mutlagúdem, which, for want of a better name, we have come to call the Jángaom river.

The Pránhita and Jángaom rivers.

The next large river is the Indrávati, of which, however, very little is seen in this area. It rises far to the eastward in the Jaipur country, and passes through the Bastar territory across a singularly terraced country arranged in three plateau uplands, the highest of which is about 2,000 feet above the sea. From the second of these, near Chitterkót,[1] some 30 miles west of Jagdalpúr, the chief town, it passes by one of the most famous falls in the Peninsula to the deeper and more rocky channel of the rest of its course to the Godávari. It is remarkable as being the only westward-flowing river of importance on the eastern side of the Peninsula. In the present area it differs from the other rivers in having, for the most part, a very rocky channel nearly with the strike of the rocks, which are of a very hard and compact character. The Godávari below the junction also has this character (only not so broken or rugged) for some miles at what is called the second barrier near Enchapali. As a general rule, this river and its other tributaries have broad sandy beds with only a few bars of sandstone or other rock, cropping up at wide intervals, bordered by far reaching alluvial flats, and are thus in great contrast to the narrow and rocky bed of the Indrávati with its frequent

The Indrávati.

[1] About seventy or eighty miles east of the present area.

streaky reefs of hard rock and tamarisk-grown ledges, with intervening pools of considerable depth.

The Mánér.

On the western edge of the field the next largest tributary, the Mánér, after flowing for many miles through the eastern portion of the Nizam's dominions, enters this area about Velchal and joins the Godávari near Arenda, thus forming with that river a triangular area of country, which will be often referred to hereafter as the Mantani *doab*.

The Pángadi Vágu and the Tál.

Below the Indrávati junction, but on the opposite bank, the Pángadi Vágu joins the great river opposite Nugur after draining a large area in the Nizam's dominions; its drainage area being entirely within the western limits of our field. Next comes the Tál, or Tálperu river, from the Bastar side of the country, entering the main river below Cherla. The Tál was, for a long time, supposed to drain a coal area, from the fragments of coal found near its mouth; but the only coal-measures in that part of the country are really just in the bed of the Godávari opposite the mouth of this tributary.

The Kinersáni and Sáveri.

Still further down, the Kinersáni falls into the Godávari opposite Bhadráchalam after completing its entire course like the Pángadi Vágu, within the western limits of the field. Both this and the Pángadi Vágu rise in small outliers of the coal-bearing group of the Gondwána formation. Lastly, and now on the left bank, the Sáveri joins the great river near Rakapali, having come southward from not far from the sources of the Indrávati.

Bends and reaches of the Godávari.

As already stated, the course of the Godávari river across this field has not such a generally straight run as that of its upper portion, being deflected from its main course at several places just before being joined by the Pránhita, then returning to its old direction for a while when there is another deflection to the eastward above the Indrávati junction. After this there is a further long south-east reach, succeeded by another east and west bend below Bhadráchalam; and then come the winding narrows of the gorge. For convenience of description and reference hereafter, these bends or

deflections will be noticed as the Mánér, Indrávati, and Sáveri bends, and the Káleswar and Enchapali reaches.

Its slack and flood times.

The waters of the Godávari and its tributaries begin to lower about the month of November and are at their lowest in June; though a slight rise may be given so early as April by the Indrávati, as rather heavy showers fall all over the Bastar country in this month and even in March. About June, however, the first freshets come down from the Deccan and Central Provinces, over which the south-west monsoon has fairly broken, and gradually the great river system gathers its waters until over all the wide alluvial flats indicated on the map are extensive wastes of water. At the narrower parts there are rises of from forty to sixty feet above the ordinary level, or at exceptional times so much as one hundred feet in the great gorge in the Eastern Ghats. And now the great rafts of timber which have been collected at all the depôts up the tributaries during the dry weather, are borne along on this mighty flood with wreck of jungle and huts and household stuff, on which may be seen at times a wondrous collection of animals of sorts even to the wily and lissome tiger. Through the gorge the pent-up waters tear their way with, I have been told, a surface so strangely concave on the cross section that adventurous boatmen glide along the bottom of a trough whose sides rise up to a good height and hide away the immediate banks; and, out of this gorge, away towards the open country of the Godávari district, the river has such a fall that the sensation produced on the mind of the traveller is said to be that of sliding down an inclined plain. Forty miles below the gorge, the flooded waters pass over the great dam or *anicut* (now hid far below and only indicated by a broad wave stretching across the river from bank to bank) at Dawlaishweram, and are then distributed over the delta by three large branches and an elaborate system of artificial canals and irrigation channels.

Its navigation.

During flood time the river is navigable by the powerful flat-bottomed stern-paddled steamers of the Godávari Navigation Works right up to the Pránhita

junction, and thence these vessels can run up the latter river to the Wardha, the smaller steamers even having gone up as far as Ballárpúr[1] on that river. In the dry weather all direct navigation on this line used to be impeded by three strong bars of rock at Dummagudem[2] and Enchapali on the Godávari, and near Dewalmári on the Pránhita, called respectively the first, second and third barriers. A magnificent navigation scheme, originated by Sir Arthur Cotton, for opening up this line of country into the Central Provinces, by passing these barriers, was so far carried out as that a dam with locks and a short canal have been erected at Dummagudem, and portions of another dam and locks have been built at Enchapali; but periods of financial depression have intervened, and so the great scheme has gradually fallen through and all that remains is that the first barrier works are kept up in only a portion of their original entirety, and navigation is possible during about two-thirds of the year as far as Enchapali where now stand the half-built anicut and locks and the crumbling walls of bungalows and workshops in a region fallen back to its primitive state of jungle and desolation.

Orography.—The country so traversed by this river system is, though being treated of as a great valley or basin, really, after all, a rather hilly tract. The proper low country consists of the low-lying grounds adjoining the large rivers, a vastly smaller area than all the rest, which is either broken by many low-scarped parallel ridges or else runs up into extensive masses of upland and even lofty hill ranges. The low country is widest and most extensive in the northern half of the field, when it narrows gradually towards the Indrávati-Godávari junction. Below Enchapali there is a further widening out and then practically a complete closing up of the basin at the gorge in the Eastern Ghâts. Near Bhadráchalam, however, the low country is connected by a narrow gap over a low watershed south of Pálúncha with the Kistna valley system.

[1] Outside this field, about ten miles from Chánda.

[2] Sometimes spelt Dumagudem, not yet entered in the Madras list of names of places. The above spelling is, I believe, nearest the true pronunciation.

The Pákál range, and the western Godávari ridges.

On the western side of the field there is a very wide and rather elevated area of mountain land lying between Hannimkonda and the alluvial plain of Mangapet, on the Godávari, consisting of a succession of ill-defined parallel ridges and terraces which range from one to two thousand feet above the sea. This mass is crossed by a wild and seldom used bullock track from Hannimkonda[1] to Pálúncha, and it may be called the Pákál range of hills from the now deserted, though once large, village of that name now known only by the great tank which remains to tell of former importance. To the north-west this range is defined by the western affluent of the Pángadi Vágu, in the Sullavai valley, but its western ridges are continued in the same direction, though now more definitely as ridges, having western escarpments and eastward dip-slopes, between which is the long flat valley of Narsapur with its large tank. These ridges, at first of considerable height, gradually lower to the Mánér valley; though even close on this river, one of them is marked by the bold headland of Encharáni, east of Velchal, which attains a height of 1,362 feet over the sea. Beyond, in the Mantani doab, there are only low and broken ridges, but to the north of the Godávari a further set runs [illegible]n the same direction to 1,070 feet as the Timapuram hills, and even beyond these again to the much loftier and more massive but boldly scarped range striking away to the head waters of the Jángaom valley.

The Gundikámáram range.

In the middle ground, between the Sullavai valley and the Mánér, lies the more compact and rugged, though still high, mass of the Gundikámáram hills, forming a great quadrilateral core as it were, along the eastern side of which the north-westerly extension of the eastern portion of the Pákál range (locally called the Kátapur hills) strikes away in low parallel ridges up to the Godávari about the Pránhita junction. This range has its high peaks at over 2,000 feet above the sea. The outer eastern ridges are low and well marked, though in the Nándigaon hill station and in

[1] Also written Hanamkonda.

the Pertabgiri range further northwards they run up respectively to 1,141 and 1,448 feet.

The hills of Chinúr and Sirpúr.

A further but much lower mass of hills in the country north of the Godávari above the Pránhita, is that north of Chinúr, culminating at 987 feet in the trigonometrical station eight miles to the north-west, which is surrounded by the low country of Angrezpali and Maleri. Yet further north-west, or between the Jángaom and Wardha rivers, there is again a larger but broken mass of hills lying to the west of Sirpúr, the highest point of which is 1,759 feet above the sea.

The Ambagúta and Dewalmári hills.

On the eastern side of the field, the belt of low country bordering the rivers is much narrower, while the hill masses rising from this are better defined, though not loftier, than those on the western side. Taking them from north to south these hill ranges commence with the small isolated mass of Ambagúta, 1,471 feet, on the right bank of the Pránhita, west of the large town of the chief of Ahiri. It is peculiar on this side of the country, being a typical western scarped range with long and well-displayed eastern dip-slopes. Some five or six miles to the south, the Pránhita flows through a group of hills, from Dewalmári to Dubagúdem, among which a great quadrilateral mass on the Dewalmári side of the river is conspicuous for its height and lofty scarped sides, particularly those facing east and south. It is a sort of basonal mass, rather low in the middle, from which there is a rise to the scarped sides.

Sironcha and Enchapali ranges.

After a short interval of valley to the south-east of Dubagúdem, there is a prolongation of this range of hills into the Sironcha country as far south as the junction of the Indrávati with the Godávari. This is a very irregular mass of hills, being made up of rocks belonging to two very different series, the younger of which has its beds nearly horizontal, while the other is of much-folded and very often exceedingly hard strata. Thus it happens that the portions of the range nearest the river have more of a plateau form, though not as much elevation as with the high scarped precipices above

Chikiála, and the Enélai plateau nearer Sironcha. Further inland, there is the broad, loftier and more rugged, though still somewhat scarped mass of the Sirkonda range, which has a trigonometrical station at 1,741 feet, and, I think, even loftier points than this on its eastern half. This range narrows considerably and falls so low to the east of Sironcha as to give a pass across it to the Indrávati valley, but it rises again into the lofty broken and ridgy mass to the east of Amarali which drops down to the level of the Godávari just above the Indrávati junction. A prolongation of the range strikes from the right bank of this bend of the great river, as the Enchapali hill which attains a height of 1,234 feet, and runs south-south-east for some ten miles, and beyond this there is then the wide flat valley of Mangapet and Nugur, which is only broken by the very small plateau range of Nursinguta. These Sironcha hills form the western side of the Indrávati valley, for the small length of it which is lying in the present field, and on its eastern side, or closing in the Bhopalpatnam country, are the western outliers of the strangely terraced uplands of the Bastar country already incidentally referred to.

The Albáka range.

Separated from these Bhopalpatam hills by a long valley going south-eastwards and from the Sironcha range and its Enchapali prolongation by the Indrávati and the Godávari, is the very extensive and remarkable range which sometimes goes by the name of the Albáka hills, from a large town on its southern end, and which at its highest point (Doli) attains a height of 3,174 feet above the sea. This range is remarkable for the great line of escarpment, nearly 50 miles long, it presents to the westward; for its extensive table-land character; for its regular, though rather curved eastern edge which is not precipitous; and that it is almost entirely composed of one rock formation. The northern end presents the finest escarpment, a grand precipitous face, looking almost vertical, fully 1,250 feet in height, which is banded horizontally by the outcropping beds of quartzite and slaty rocks composing it and furrowed and seamed with many a dry stream bed and innumerable joint fissures. Further south, the western face is broken up into several lines of

escarpment one above the other, and these go contouring in and out at the many deeply-cut streams and torrent valleys; while, owing to the gentle hade or rise of the beds to the south-west lower and lower bands of quartzites rise up and give more and more scarped lines towards Albáka, until the highest of all, now lying well back from the river face, runs up to over 3,000 feet. At the southern end, the lines of scarped cliffs run right round to the eastern side, but they soon slope down again to the long valley at the back of the range, whence, further north, as from Yelmidi past Madder, there is a more or less dip-slope to the range.

Opposite Albáka the range itself ceases; but there are outliers nearly as far as Cherla, and the first of these, namely, that immediately north of Kotapali, is a magnificent specimen of a small but lofty table-land whose sides are all scarped in lines of cliff and terrace for a great height above the undercliff at the base, while it is inaccessible, except by a difficult path on the Kotapali side.

The Albáka hills are all covered with low and thin jungle, which brightens up and looks thick in the rains, but which all becomes dry and leafless in the hot weather; in fact, there appears to be little soil for luxuriant growth, and there is no holding power in the flat strata for the abundant fall of rain which must take place at certain times of the year. There are only a few small assemblages of huts scattered over the plateau at wide intervals; and the range is only accessible by a few difficult foot and cattle tracks, which probably accounts for no attempt having been made to reside up there during the hot weather by any of the generally adventurous men who were stationed from time to time on the Godávari Navigation Works.

The Mámla hill and its outliers.

To the south, about Cherla there are a few low outliers of this range reaching as far as Tegra, and then comes the Godávari bed; but in the same line, though now turning more southward, and on the opposite bank of the river, there is a prolongation of the range in the Rotangúta or Mangur hill, opposite Párnasála, which has an escarpment facing eastward. Still a little further to the westward, and of the same rocks, comes a large hill mass

which must be considered as a distinct range for it is separated from the Rotangúta hill by a clear valley and from the great Pákál range to the westward by yet another valley round by Búga and Bungarchilka, and this may be called the Mámla range. It possesses neither the scarped character of the Rotangúta ridge nor the plateau form of the Albáka hills, nor yet the more rounded outlines of the eastern portion of the Pákál mass; but is a lofty, 1,800 feet, and irregular mass of serrated ridges, that nearest to the river being very steep on its eastern face.

Kunnigiri hill, &c.

To the south of this range and the Kinersáni Vágu, are lowering and ridgy prolongations of the Pákál range which dip down into the plains of Kummummet, flanked on their eastern side by the Pálúncha valley which connects the Godávari basin with that of the Kistna. In this Pálúncha depression, there is, again, the small but lofty isolated mass of Kunnigiri which is about the most easterly of the great hill fortresses erected under the Telingána dynasty of the Aryan conquerors of India.

The Dummapet hills.

Lastly, and forming the eastern side of the Palúncha valley is a large irregular, though not lofty, group of hills lying between the Sáveri bend of the Godávari and Ashwarowpetta, which may be called the Dummapet range, and this is separated from the Eastern Ghâts range by the low watershed at Beddadanol which is marked by the most easterly and southerly outcrop of coal-measures in the Madras Presidency.

Wild character of the country.

Topography.—Nearly the whole of the area under description is a wild jungle-covered and very thinly populated land, rarely visited by Europeans except at one or two points, and only traversed by a fairly made road between Hannimkonda and Mangapet in its middle western portion. Other short roads lead into it from the Godávari district on the south, or from Chánda on the north, but these soon die out into the ordinary dry-weather cart tracks the chief of which runs up the main valley. Indeed, had it not been for the starting of the out-of-the-way civil station of Sironcha and the carrying out of the navigation works,

the land might have been yet in great part, except for the marvellous labours of the Great Trigonometrical Survey, a *terra incognita* to all but a few adventurous travellers and sportsmen; and it is still practically, what it has been for ages, the home of a great portion of the old Pre-Aryan race of the Kois or Gonds and a centre for the huge trains of grain and salt-carrying pack-bullocks of the wandering Brinjáris who find this region well adapted for their temporary settlements and feeding grounds.

Evidences of former civilization.

There was a time, however, if we may judge by the ruins of many large forts splendid temples and great tanks scattered over the middle-western portion of the country, when a very different condition of the inhabitants and cultivation of the lands existed. This was under what appears to have been the more benign sway of the Aryan conquerors, when Warungul, near Hannimkonda, was one of the royal cities of the Telingána dynasty, though it is now a desolate ruin, nearly two miles in diameter, of huge outer *vallum* enclosing an inner stone-faced circular wall, within which only a few poor villagers are gathered round the defaced palace where a poverty-stricken Muhammadan laird and his armed following idle their lives away in pride and dust.

The Pakál and other tanks.

The tanks of Pákál, Palliampet, &c., to the eastward of Warungul are wonders in the way of storage of water; the former is the most extensive of these, with a high embankment or bund about a mile in length, behind which the waters, as it were of a lake, are spread out over a superficial area of about 17 square miles. The shoreline winds in and out among minor ridges and low hills, which also, in their extension into deep water, make two large hilly islands. Below the bund there is now a large patch of dense jungle, which is sometimes the resort of a stray elephant from the Nizam's stud, and beyond is the old flat of once cultivated rice grounds, now only taken up here and there by a few poor settlers.[1]

[1] During the famine of 1878-79 very many of the starving people of the eastern portion of the Nizam's Dominions wandered to this tank ground to linger over the few roots and edible portions of the jungle growth still left there.

By far the greater portion of the area is in the Nizam's Dominions; in fact, all the country to the westward of the Godávari, Pránhita and Wardha is only a portion of the huge territory of the Ruler of Hyderabad in the Deccan. On the eastern banks of these rivers are the Central Provinces and the Godávari district of British territory, though the greater part of this country belongs to the Chief or Rájah of Bastar and the minor Rájahs of Ahiri, Bhopalpatam, &c. The towns of importance are Sironcha (now reduced to an Assistant Deputy Commissioner's station of the Chánda district) in the Central Provinces; Dummagudem, Bhadráchalam, and Chintalpudi in the Godávari district; and Hannimkonda, Kummummet, Sullavai, Pákál, Ashwarowpetta, Chinúr, and Sirpúr in the Nizam's Dominions. None of these, however, are of any great importance as centres of population or of trade[1]; they are mainly stations of official jurisdiction, or of religious assembly as Bhadráchalam, or connected with the navigation works.

Territorial divisions and towns.

CHAPTER II.—GENERAL GEOLOGY.

Rock series.—Before entering on a more detailed description of the rocks, it will be as well now to give a brief account of their sub-divisions, their bearings on the physical geography of the country, and the manner in which they have been worked out by previous observers and the Geological Survey.

The different formations are presented in the following table according to their local grouping in descending order; and they are also

[1] Hannimkonda is always talked of, in other parts of Hyderabad, as being famous for its manufacture of arms; though the visitor will now find considerable difficulty in obtaining anything else but the short straight daggers—some of them beautifuly damascened—which every man of any consequence carries in his belt. Warungul is famous for its striped cotton carpets. In the same district, Pemburty, some 30 miles south-west of Hannimkonda, is a place of manufacture of articles in brass, particularly candelabra, some of which are quite unique in design. However, as in all other places of special manufacture in secluded parts of India, samples of those industries are seldom kept on hand by the workers, and thus it is difficult for a passing traveller to obtain the articles; in nearly every case, orders for such must be given fully a month beforehand, and the price is always exorbitant.

correlated, as far as possible, with the Survey and European systems of classification :—

Local groups.	Survey classification.	Approximate European classification.
Alluvium ...	*Alluvium* ...	*Recent.*
Fossil wood and *Implement gravels.*	*Older alluvial deposits of the Godávari.*	*Post-Pliocene.*
Traps of Jángaom Valley	*Lower Deccan Traps* ...	*Upper Cretaceous.*
Chikiála sandstones ... *Kota beds* ... *Maleri beds* ...	*Rájmaháls* ? ..... } Upper Gondwánas.	*Middle Jurassic* with Triassic affinities. Having Triassic affinities.
Kámthi sandstones ... *Barákar sandstones* ... *Tálchir beds* ...	*Kómthi, Damúda.* *Barákar* *Tálchir* } Lower Gondwánas.	Triassic and Upper Palæozoic.
Sullavai sandstones ...	? Karnul Series. { ? Lower Vindhyans. }	? Lower Palæozoic.
Pákál Series ...	Kadapah Series. { Upper Transitions. }	? Pre-Palæozoic.
Gneiss ...	Gneisses of the main or eastern region of the Peninsular area.	Azoic.

Fossil remains.

It is only in the upper members of the lower Gondwána formation that any palæontological evidence as to the relations of these rock groups begins to appear. The Tálchirs and Barákars appear to be quite barren; and the Kámthis themselves are only fossiliferous at rare intervals.

The upper Gondwánas have been long known in this region for their fish and reptilian remains; and plants of Rájmahál age have, within the last few years, been found in certain beds.

The Deccan traps being only poorly developed in this area, there was little chance of their usually widely separated lacustrine intercalations being found here, and thus they, too, are barren.

On the other hand, the occurrence of silicified fossil wood in the Godávari gravels is remarkably large and extends over a considerable

area; while chipped quartzite implements[1] are occasionally found associated with the fossil wood.

Distribution of the formations.

As in most other great areas of Peninsular India the all-prevailing gneiss is the basement or floor rock of this field, on either side of which it extends for a hundred miles or so into the Bastar and Hyderabad countries. Between these flanking areas of crystalline rocks, and striking north-north-west and south-south-east for nearly three-quarters of the length of the field lies a wide belt of the Transition and lower Vindhyan rocks, which only show by an outcrop on either side, being covered up and over-lapped by a long and narrow intervening belt of Gondwána strata stretching right along the middle area from end to end.

At the north-west corner of the tract, there is just a small eastern prolongation of the great spread of the Deccan traps, and a few outliers lying on Transition and Gondwána strata. Then, spread all over the field and covering up the other rocks in the most disappointing way, or down in the river valleys, are the post-tertiary gravels and clays and the more recent alluvium of the rivers.

Their relations.

On the face of the map itself, it will be seen that these formations are strongly and absolutely separable from each other. The gneiss widespread and fundamental, *par excellence*, for this part of India, the dip of its foliation being usually at a high angle, or even vertical; and then, the Transition and Vindhyan strata lying easily, or rolling somewhat, or folded over the floor rocks, or squeezed and faulted against these in abrupt juxtaposition.

In a previous memoir[2] I have treated of the, at times, great difficulty there is in separating the Transition rocks from the gneiss series; but here there is only a very slight trouble in this way at the southern end of the field, which is indeed only the northern extension of the disturbed area in the Nellore and Kistna districts described in the work just

[1] Smooth stone axes have also been found by me in the southern part of the field, but these are not so evidently from the old gravels.

[2] Mem. Geol. Sur. of India, Vol. XVI, Part 2.

quoted; and, on the whole, the absolute separation of the Kadapah Transitions of Pákál from gneiss is as clear as noonday. There is, however, a close connection between the Pákál Kadapahs and the Sullavais, though the complete overlap shown on the map still keeps them as widely apart as the Kadapahs and Karnuls [1] of the Kistna and Pennér valleys.

The sub-metamorphism or altered character of the Pakáls is very clear; but there is only partial alteration exhibited locally in the Sullavais, and there is not a sufficiency of lithological resemblance between them and the Karnuls to admit of close correlation.

The perfect separation of the Gondwánas from the Transitions and Vindhyans is here exhibited in all its reality, and the mode of occurrence of this formation shows, with some precision, how different this portion of the land surface of the peninsula must have been in palæozoic times, in the existence of a depression or valley, very much in the line of what is now being described under the name of the Pránhita-Godávari basin.

The grouping of the Lower Gondwánas into Tálchirs Barákars and Kámthis, is very clear, as shown in the cases of overlap in the southern portion of the field, both in the main area and in the outliers, as also, but less certainly, in the north-west area. There are also indications of a separation from the Kámthis of an upper member which may be of Panchet age, but these are not sufficiently clear to be acted on in the delineation of a group on the map.

The separation of the upper Gondwánas from the Kámthis has been our great difficulty throughout the long survey of this field, trammelled as this investigation was by close lithological resemblances and above all by the way in which the rocks are covered by superficial deposits and jungle. The occurrence, or, rather, supposed association of animal remains having triassic and liassic facies in groups of this formation was

[1] Mem. Geol. Sur. of India, Vol. VIII, Part I. The Survey having originally adopted the proper spelling, Kadapah and Karnul, for these two names cannot now revert to the old style, Cuddapah and Kurnool, although these are allowed to stand in the authorized official list of Indian names.

also extremely puzzling until it was found that these remains are really in different groups.

There was then the further sub-division of these upper Goudwánas into groups, two of which are distinguished by their fossil contents and lithological difference: while the third and newer is not so clearly a member of the series as I was inclined to suppose early in the progress of the survey. The Chikiála sandstones, though strongly resembling in their constitution strata of the coastal jurassic deposits, do nevertheless present such indications of an unconformable lie on the Kota beds, that it is quite possible they may turn out to be really of a newer formation altogether. At the same time I do not feel justified in placing them out of this series, and so have left them as doubtfully an upper group.

The strong unconformable lie of the small remnant of the Deccan traps, in the north-west corner of the field, over beds of Barákar, Kámthi, Maleri and Kota age sufficiently testifies to the great interval of time and physical change which must have occurred in this region between the uppermost jurassic and upper cretaceous periods.

Connected areas of these rocks in Southern India.

The completion of the survey of this region enables us now to connect the geology of the Madras Presidency with that of the great central or middle portion of the peninsula; and reference to the geological map attached to the Manual of the Geology of India, as well as to the several memoirs, with their maps, relating to the neighbouring countries of Nágpúr and Chánda, the Deccan, the proper Godávari district of the Madras Presidency, and so southwards to the Kistna, Karnul, Kadapah, Nellore, and Madras districts, will show the combined areas of the formations to nearly their full extent. This view of them will also aid in the discussion of some generalisations as to the past and present physical geology of the eastern side of the peninsula.

Transition land surface.

Physical Geology.—In the first place, and with regard to the Transition land, it would appear that its western edge must have had for the greater part of its length very much the outlines indicated by the present western bound-

ary of the transition rocks. In the Kadapah district, at least, the western outcrop is of well marked shore beds, and I do not think the upper beds of the series extended much beyond their present limit.[1] In the Kistna valley, about Karnul, the shore facies of the rocks is still clear, but the presence, at only about seventy-five miles to the north-west, of similar quartzites and slates in the Kaládgi district and on the Bhima[2] seems to show that these areas may have been connected by an area of the Transition waters.

Further down the Kistna, at Jaggayapet the northern limit of the Kadapah and Karnul field is reached, and nothing more is seen of these Transition and Vindhyan rocks until north of Kummummet, in the southern part of the present area.

The western boundary of the Pákál Kadapahs is again somewhat like that of the Pennér and Kistna region in being a shoring edge, though not so clearly a near shore line, and its western limits also cannot have extended very much beyond the present boundary (indeed it is overlapped by the Sullavai series), until north of the Godávari river, when in the Jángaom valley region it appears to have spread out again to the westward.

The eastern edge of the whole Madras and Central Provinces area of the Transition rocks is, on the other hand, for the greater part of its length, a more or less faulted line; though on this side too, in the middle, it evidently was spread out to the eastward and was probably continuous with the Bastar area[3] of the same rocks, the nearest western edge of which is now about 80 miles east of the present field in the high plateau land of Chitterkot.

Looked at largely, the land surface of the eastern side of India in the Transition period must have been much foreshortened to what it now is;

[1] See Mem. Geol. Sur. of India, Vol. VIII, Part I.

[2] See Mem. Geol. Sur. of India, Vol. XII, Part I (R. B. Foote).

[3] See Records of the Geol. Sur. of India, Vol X, p. 179 (Ball). I have myself, since the publication of Mr. Ball's paper, connected the survey of the Godávari valley with that of Bastar, at Chitterkot, and the rocks there exposed are similar to some strata of the Pákál series.

or, at any rate, there must have been a wide water area to the north-east of a coast which probably curved round very much as the western edges of the present fields of Transition rocks, with perhaps a large indentation towards what is now the Kaládgi region.

The Gondwána land, and its drainage.

The next great change in the land surface is shown by the lie of the Gondwána formation which, as will be seen on the larger map of India, occupies a line of country ranging in a south-east direction from the south side of the Narbada valley at Pachmari down to the Godávari coast, and so southwards along the Coromandel even to the Trichinopoly district; the coastal deposits being essentially marine[1] as distinguished from the fluviatile and lacustrine character of the formations extending from them to the Narbada. In this new phase, the land surface was extended very considerably to the north-eastward; but it was traversed by a great valley or area of deposition—in part, very much in the direction of the present valley, between Sironcha and Bhadráchalam—the distinguishing feature of which was that it appears to have been connected with a drainage system extending over what is now the eastern part of the Peninsula.

The straightness of the depositional area.

This narrow belt, of Gondwána rocks, indicative of the presumed valley, has, however, a remarkable apparent straightness of outline, especially on the north-east edge, which presents strongly the character of a faulted boundary, and which is indeed considered by a large and widely experienced section of the Survey to be really faulted, and only a further example of similar straight-edged fields of Gondwánas in Chota Nágpur and the Narbada valley. From this it is argued that the rocks may not have been deposited in a truly denuded narrow valley, but that a great strip of an originally more extended area has been let in and preserved here among the older rocks by a system of faulting. This eastern edge is no doubt very straight; but closer examination of the field tends, I think, to show that it is, after all, a natural boundary: straight on the whole, but in its details less so, every now and then curving slightly in among the spurs and indenta-

[1] See Manual of the Geology of India, Part I, pp. xxxvii, 147.

tions of the older rocks; while the faults which do exist are either local or belong to a pre-Gondwána age. All the conditions of the boundary seem to me to be simply such as would be presented if a series of deposits were laid down along a straight shore line, like that, for instance, which would be given by a great length of the Eastern Ghâts in the Nellore District were the Coromandel submerged some 500 feet below the sea; hence this straight-sided strip of rocks may merely indicate an exceptional form of valley denudation.

On the whole, then, the present belt of Gondwána strata may be taken to represent very fairly the direction and width of a valley or depression, which lay across the middle of the Peninsular region, and which was very possibly flanked by the hilly land which is now more definite as the eastern ranges of Albáka and Sironcha.

Post-Gondwána denudations.

Henceforward, and up to the close of the mesozoic period, there are no rocks in the present field to give us a clue to the close defining of any great physical changes which may have taken place in this part of the Peninsula: all we know is that Gondwána times must have faded away, and that later movements of the earth must have brought their rocks under the denuding influences of a new drainage system; and that on this denuded surface there is now left only a very small remnant of the tremendous volcanic discharges which covered so great an area of the Deccan in later cretaceous and perhaps eocene times.

Age of the Godávari river.

I have, elsewhere,[1] in describing the rocks of the lower Godavári, endeavoured to show that this river, in its course through the Eastern Ghâts, has cut its gorge in an old marinely denuded surface of the gneiss and the lower Gondwánas of the coastal region; that is, that the river for so much of its course is of newer age than the latter rocks. A glance at the map of the present field will show how the higher course of the river is altogether in and across strata of both divisions of the Gondwána system, and that thus, close as it may now appear to run for a certain distance

[1] Mem. Geol. Sur. of India, Vol. XVI, Part 2.

in the ancient Gondwána system of drainage, this important and very ancient looking river is really only of post-Gondwána age, and could have had no existence at the earliest until after the middle of the mesozoic period.

It might on this be suggested that the drainage system of this river is also cut in the Deccan traps; but all that can be reasonably concluded from this is that its higher tributaries are perhaps of tertiary age. It may be that the Deccan traps did once extend much further to the east and south, and that the main area and the outlier near Rájamundry were connected, in which case a much later age would have to be assigned to the river, but there is little evidence to show that this ever could have been the case. The course of the Godávari is certainly across the traps at Rájahmundry, but this might easily have been brought about in the elevation of the Coromandel which brought the traps and estuarine fossiliferous intertrappean beds under the influence of denudation, long after the main valley and the gorge had been carved out. All I wish to place before the reader is the possible age of the main Pránhita Godávari valley.

Two periods of fault movement.

There have been two very decided periods of disturbance or movement in the field which have left their traces in the form of faulting, or alteration of the strata by crushing in certain formations, though local faulting is occasionally seen among all the rocks; the one in pre-Gondwána or probably palæozoic times which only affected the gneiss, the Kadapahs, and the Sullavai rocks, and the other, of mesozoic age, the effects of which are displayed more or less in all but the Chikiálas and the Deccan Trap.

Pre-Gondwána faults.

Originally, the Kadapah rocks appear to have occupied a widely extended area, which had, however, its western boundary very much along the line now displayed on the map; but a great movement was superinduced on this part of the earth's crust whereby the gneiss rocks and, with them, the area of Kadapah strata were tremendously crushed up from the eastward, more particularly in that region which is now a portion of the Kistna

valley. At least, this is the conclusion which must be drawn from the very altered, schistose, crushed-up, and folded condition of both series in the southern or Kummummet region of the field.

Just at the southern end, the western edge of the Kadapahs has an abrupt and faulted boundary for a short length; but away past Hannimkonda and right up across the upper reach of the Godávari there is, for the most part, a natural boundary. On the other hand, the eastern edge is marked in the Godávari about Dummagúdem by very abrupt and altered boundaries of the Kadapahs against the gneiss, and thence northward by fewer and fewer evidences of crushing right round by the back of the Albáka range past Bhopálpatnam up to Dewalmári, where, however, the faulting and crushing are again strong and displayed in the Sullavais, as well as in the Kadapahs and the gneiss.

Near Dewalmári, or a few miles beyond it, there is an extension of this system of faulting in the hill ranges; but there is also another line extending from Bijur up to the Wardha which brings the Gondwánas also against the gneiss, only this must belong to a later system altogether.

There was also, in the older system, I am inclined to think, a run of dislocations right up the Godávari on the western side of the Albáka range, in the Kadapah rocks, which gave a line of weakness for the denudation of the Gondwána floor in so straight a line along its eastern side, thus giving the apparent faulted edge to the strata which were subsequently deposited on this floor.

The pre-Gondwána dislocations are striking generally north-west to south-east, or else round from this to the south or south-west; but they are never more east-and-west than this.

Post-Gondwána breaks.

The next marked evidences of movements are in the Gondwána strata; but these run either along west-north-west to east-south-east lines, or nearer to east-and-west. The main faults are represented by the long Chinúr line, in the middle of the field, which strikes east-south-east, or nearly so, from Waripet in the Timapúram hills to and across the Godávari below Chinúr; and by another still further westward, on the Mánér, between Julapali and

Kápra, whereby the Gondwánas are brought against Sullavais, Kadapahs, and gneiss. The second system is represented by the east-by-north to west-by-south faults, striking to the south of and past Madapúr.

Literature.—This region has naturally, owing to its wild and difficultly accessible condition, received but little attention from scientific men until within the last twenty years or so; still, so far back as 1819, the country between Hyderabad and the Godávari was being traversed by the party of the Great Trigonometrical Survey under Colonel Lambton, and at that time, Dr. H. H. Voysey was attached to it as Surgeon and Geologist. His observations were collected, and appeared[1] in 1833, long after his death; they refer, however, more particularly to the country to the west than to the proper Pránhita-Godávari basin. He touches slightly on the Godávari valley, and describes, generally, the sandstones extending from the north of Ellore past Pálúncha. The gneisses around Garíbpet are described; and he visited the garnet mines in the neighbourhood, when he also observed the association of kyanite with what were then considered precious stones. He also describes, shortly, the occurrence of the great clayslate belt between Pálúncha and Baiáram.

Dr. H. H. Voysey, 1833.

Dr. Voysey also gives a short description of two springs near Bhadráchalam and Dummagúdem, which, as I did not visit them myself, are here reproduced for the information of any future explorer who shall have more time at his disposal than I had, or be more fortunate as to the time of his visit.[2]

"There are two hot-springs. One called Gondala is situated in the sandy bed of the Godávari, about two furlongs from its left bank, a few miles below the pagoda of Bhadárachalam. It is covered in the rainy season by the river, but is left dry during the greater part of the year.

"The bed of the river, about one mile and a half wide, contains granitic sand, above which appear rocks of granite and trap mixed in various ways.

[1] Voysey: Journ. As. Soc., Bengal, Vol. II, pp. 298—305, and pp. 393—405.

[2] These springs were also visited by Mr. Blanford; Rec. Geol. Sur. of India, Vol. IV, p. 111.

"The spring is situated close to these rocks. When I visited it in February, it was covered with sand, and we were obliged to dig in three places before we discovered the hottest part. Around this spot to the distance of fifteen yards, the temperature of a stick thrust into the ground was sensibly raised; and on digging to the depth of three or four feet, water was found hot, but of an inferior temperature to that of the central spot. Its temperature at sun-rise was 139°, that of the others 120° and 130°, whilst that of the air and river was 70°. The falling-in of the sand, the pit being about four feet deep, so evidently reduced the temperature, that it is very probable we should have found it much higher on digging deeper, which we were prevented from doing by the inconvenience the labourers suffered from the hot water. The presence of sulphuretted hydrogen was sensible to the smell; but the impregnation was not strong enough to blacken a silver pencil-case; the tissue of a slipper was slightly discoloured on being dipped into the water.

"On evaporating 2,880 grains, six grains of saline matter were left behind, consisting of sulphate of soda, common salt, and muriate of lime.

"It is much resorted to from its supposed efficacy in curing cutaneous disorders. It is worthy of remark that the rocks in the neighbourhood contain no iron pyrites. Its heat, therefore, cannot be ascribed to the spontaneous combustion of that mineral.

"On the opposite bank of the river is a bluff rock of sandstone, through the crevices of which water infiltrates, and is collected in small reservoirs, caused by the continued dropping on the soft stone. Its temperature at nine o'clock was 68°. I do not consider this to be the mean temperature of the place, since its latitude, 18° north and height above the level of the sea not exceeding 130 feet, would make its mean temperature much higher. It is called by the natives, 'the cold spring,' in contradistinction to its neighbour Gondala.

"About 30 miles to the north-west of this place is the hot spring of Bangah, situated in a valley surrounded by sandstone rocks. It is a pool of water, about 40 feet long by 20 broad, and five feet deep. From

the deepest part a number of bubbles of air or steam are continually ascending; there its temperature is 110°, but at the sides 100°. It holds in solution a small quantity of carbonate of lime. It is surrounded by loose blocks of a porous black limestone; the water is tasteless and remarkably pure in other respects."[1]

Dr. W. Walker, 1841.

In 1841 Dr. W. Walker, of the Madras Army, examined a good deal of the country between Hannimkonda and the Pránhita valley, and the out-turn of this was five papers,[2] in all of which he refers to rocks of this country. His most important work was at the Kota beds; but here he was unfortunately misled by what he supposed to be the presence of carboniferous fossils (fish scales, which he took to be scales of the plant *Lepidodendron*) in the limestone, and some poor coaly shales. He did not himself visit the supposed anthracite outcrop at Dantimpili, which village is said to be near Tándur on the north-west edge of our field, and this was doubly unfortunate for him, as he would here have most likely met with the true coal-measures of India, the Barákar outcrops near the latter village. As with myself, he appears to have been much attracted by the size and beauty of the Pákál tank, which, however, hardly comes up to his comparison with European lake scenery. He thus writes:—"This Pákál tank (for the name of lake is scarcely in accordance with its artificial embankment) is a fine sheet of water, and takes precedence of all the tanks in Telingana, both as to depth and extent of surface. It is at least thirty miles in circuit when quite full, and, besides affording a deep and copious stream for the purposes of irrigation, sends a tributary to the Kistna, which even at this season of the year merits the name

[1] Voysey: Journ. As. Soc., Bengal, Vol. II, p. 396.

[2] Walker: Memoirs on the coal-field at Kotah, &c., with a note on the anthracite of Dantimpilli (H. H. the Nizam's dominions).- Journ. As. Soc. Bengal, 1841, Vol. X, p. 341.

Report on Productions, &c., in the district of Hummumkoondah in the dominions of H. H. the Nizam of Hyderabad.—*Ibid.*, p. 886.

On the Geology, &c., of Hummumkoondah.—*Ibid.*, p. 471.

On the Natural Products about the Pundalah river, H. H. the Nizam's territory.—*Ibid.*, pp. 509 and 725.

Report on boring for coal at Kotah, Madras Journ. Lit. & Sci., Vol. XVII, p. 261.

of a small river. It is bounded on three sides by low hills covered with wood, and, although the vegetation is now parched and burnt up, picturesque beauty is by no means wanting to the landscape. Immediately after the rains it is quite conceivable that it may vie in scenery with the better known and much lauded Italian lakes. Considering its extent, its value is small, for its whole circumference to some depth is occupied by a dense jungle, and fifteen hundred bigahs under cultivation from its irrigation are but slender tribute to the chief of tanks. The situation is said to be unhealthy for at least eight months of the year, which may account in part for its thinly-peopled neighbourhood."[1]

Sir P. de M. G. Egerton, 1851 and 1878.

The fossil remains found at Kota were sent to England in 1851, when they were examined and described[2] by Sir Philip de Malpas Grey Egerton, who, also, later still, in 1878, on further and more complete collections having been placed before him, contributed a complete memoir, "On some Remains of Ganoid Fishes from the Deccan," to the volumes of the Palæontologia Indica.

Mr. Philip Wall, 1857.

The reputed existence of coal at Kota, and the finding of carbonaceous fragments, or even fragments of true coal at various points down the Godávari, kept up the expectation of the ultimate discovery of an outcrop or seams of this much-desired fuel; and in 1857 Mr. Philip Wall was engaged as Mineral Viewer by the Madras Government, and sent up and down over the country wherever coal or other minerals were supposed to occur. I believe Mr. Wall himself informed the Government that he was more properly fitted for the exploration of a country in which coal rocks were actually known to exist, rather than for the finding of such a formation, which might not necessarily always present the same characteristics as the coal-measures of England. However, he was sent up the Godávari valley, and his report appeared in the Madras Journal of Literature and Science;[3] and this is what he says early in its pages:—"In the

[1] Journ. As. Soc., Bengal, Vol. X, p. 472.

[2] Quart. Journ. Geol. Soc., London, Vol. VII, p. 272, 1851.

[3] Vol. XVIII, p. 261, 1857.

course of my examination of these sedimentary beds in my march up the river, I found nothing in the remotest degree approaching to those indications which are met with in European coal districts, neither in my examination of the pebbles in the river did I discern anything of this nature." To a certain extent he was right; but all the same, coal was ultimately found near Dummagúdem, on the suggestion of Mr. W. T. Blanford, and again in the Jángaom-Pránhita country by Mr. Hughes: only the coa is in the coal-measures of India (the geology of which my colleagues had both in great part worked out), and not, as Mr. Wall naturally expected it to be, in the rocks of the carboniferous formation of England, of which there are none as yet known in the southern part of India.

As it was, Mr. Wall made a very interesting examination of the Pránhita-Godávari valley, during which he noted the occurrence of the Transition series in the neighbourhood of Cherla and in the Álbáka hills, and the presence of various sandstones, limestones, and red clays, &c., all of which have since been found to occur in the several groups of the Gondwána formation, from their southernmost point below Bhadráchalam, up to Mutlagúdem on the Pránhita. Seeing them only in a traverse up the immediate bed of the river, these rocks apparently lying one on the other, with only a few exhibitions of dislocation here and there, he took them to be all of one series, and based his generalization as to their non-coal-bearing qualities mainly on the Kota limestone boring and what was known of the age of the fish remains in these rocks. Once or twice he fell into the error of confounding the Kota limestones and their red-clays with limestones and red-shales of the Kadapah series in the neighbourhood of Enchapali and at Dewalmári on the Pránhita.

The Revd. S. Hislop, 1857.

The first definitely geological and palæontological work of real value in the field was, however, carried out by the Revd. Mr. Hislop, in continuation or extension of his explorations in the immediate neighbourhood of Nágpur; and with the aid of his native collector Virápa, he succeeded in obtaining a large and most valuable collection of fish and reptilian remains from the

neighbourhood of Maleri in the Jángaom-Sironcha part of the field. These discoveries date from about 1856, and have been referred to several times in our memoirs.[1]

Prof. T. R. Jones, 1863.

In 1863 Prof. T. R. Jones contributed to the palæontological literature of these rocks in "A Monograph of the Fossil Estheriæ,"[2] and in a paper to the Geological Society of London.[3]

Geological Survey of India, 1859-80.

The work of the Survey in this field is given in its publications[4] and will be noticed when necessary in the following pages.

[1] Vol. I, p. 297; IX, p. 327; and Rec. Geol. Surv. of India, IX, pp. 86, 134; X, pp. 29, 61. Also, Quart. Journ. Geol. Soc., London, 1861, XVII, p. 348; 1864, XX, p. 280; and Journ. Bombay Br. R. A. S., 1861, VI, p. 202.

[2] Pp. 81, 127.

[3] Quart. Journ. Geol. Soc., 1863, XIX, p. 149.

[4] 1859. *Oldham, T.*—On some fossil fish-teeth of the genus *Ceratodus*, from Maledi, south of Nágpúr, Mem. Geol. Surv. of India, Vol. I, p. 295. Also, 1871, sketch of the Geology of the Central Provinces, Rec. Geol. Surv. of Ind., Vol. IV, p. 69.

1871. W. T. Blanford.—Note on the plant-bearing sandstones of the Godávari valley, or the southern extension of the rocks belonging to the Kámthi group to the neighbourhood of Ellore and Rajámandri, and on the possible occurrence of coal in the same direction.—Records Geol. Surv. of Ind., Vol. IV, p. 49. Report on the progress and results of boring for coal in the Godávari valley, near Dumagúdem and Bhadrachalam.—*Ibid.*, p. 59. Additional note on the plant-bearing sandstones of the Godávari valley.—*Ibid.*, p. 82. Descriptions of the sandstones in the neighbourhood of the First Barrier on the Godávari and in the country between the Godávari and Ellore.—*Ibid.*, p. 107 and Vol. V, p. 23, 1878. On the stratigraphy and homotaxis of the Kota-Maledi (Maléri) deposits.—Pal. Indica, Ser. IV, 2.

1877. T. W. H. Hughes.—The Wardha valley coal-field, Mem. Geol. Surv. of India, Vol. XIII, p. 1, 1876. On the relation of the fossiliferous strata at Maléri and Kota, near Sironcha, Central Provinces, Rec. Geol. Surv. of India, Vol. IX, p. 86, 1878. Notes on the Geology of the Upper Godávari basin between the river Wardha and the Godávari near the civil station of Sironcha.—*Ibid.*, Vol. XI, p. 17.

1872. W. King.—Notes on a traverse of parts of the Kummummet and Hanamkonda districts in the Nizam's Dominions.—Rec. Geol. Surv. of India, Vol. V, p. 46. Notes on a new coal-field in the south-eastern part of the Hyderabad (Deccan) territory.—*Ibid.*, p. 65. Note on a possible field of coal-measures in the Godávari district, Madras Presidency.—*Ibid.*, p. 112, 1873. Note on Barákars (coal-measures) in the Bedadanol field, Godávari district.—*Ibid.*, Vol. VI, p. 57, 1877. Note on the rocks of the Lower Godávari.—*Ibid.*, Vol. X, p. 55, 1880. Additional notes on the Geology of the Upper Godávari basin in the neighbourhood of Sironcha.—*Ibid.*, Vol. XIII, p. 13.

CHAPTER III—ECONOMIC GEOLOGY.

The most important industrial products are coal and iron; but these only occur at wide intervals. Gold also, in small quantities, is said to be obtained from the sands on the right bank of the Godávari near Mangapet.

Coal.—The better known outcrops of Barákar strata showing workable coal of any value are in the southern part of the field; on the Godávari itself, at and near Damercherla some ten miles above the Sáveri junction, and at Lingála just below the mouth of the Tál. To the westward of these, in the Pákál hills and their extension southwards, are the two fields of Kámawaram and Singareni, and a less known outcrop in the Bundalla valley. The most southern outcrop at Bedadanol did not, on being bored, show any useful coal; and, as there did not seem to be any chance of such being found by further boring in British territory, the exploration was discontinued. Barákar outcrops occur again on the Godávari above the Pránhita junction, and right away in the north-western corner of the field where they have been followed out in extension of the Wardha valley coal-fields. I will take these fields in order from the Wardha valley.

Antargaon outcrop.

Antargaon.—Coal is marked in Mr. Hughes' map of the Wardha valley coal-field as occurring a short distance south of Antargaon; and of this he writes:[1]—"Coal occurs at Antargaon, a little south of the Láthi Ghât. It does not form the top bed of the measures, as in so many other parts of the field, and I cannot say positively whether it is the representative of the thick seam. It can only be examined by digging away the river mud that overlies it; and then the following section is exposed;—

						Ft.	In.
Coal	...	...	...	...	...	2	6
Shale	...	...	...	...	...	0	9
Coal	...	...	...	...	...	2	9
				TOTAL	...	6	0

The direction in which it dips is not well defined; but it has a general slope to the north-east. The coal presents a very fair appearance; and

[1] Mem. Geol. Sur. of India, Vol. XIII, p. 63.

though the analyses of the samples that I forwarded to the Geological Survey Office do not indicate a high class of fuel, it must be borne in mind that the specimens submitted to examination were from the surface. Taking no note of the water (8·7 per cent.), the composition of the coal is:—

Carbon	...	...	...	...	51·26
Volatile	...	...	...	...	28·25
Ash	...	...	...	...	20·49
			TOTAL	...	100·00

"An anticlinal, west of Antargaon, causes the dip of the Barákars near the base of the hills that sweep round from Anúr to be in a reverse direction to that seen in the river; and I believe the Antargaon seam is again exposed in the portion of the Anúr range called Kondai-ka-pahar, dipping south-south-west at 10°. At all events, a bed of coal, 5 feet thick, crops out a short way up the face of the hill. The place where it occurs is not an easy one to find, but near it is a trickling fall of water in the cold season, strongly impregnated with calcareous matter. * * * Immediately above the coal is carbonaceous shale 3 inches, then carbonaceous sandstone. The boundary of the Kámthis occurs higher up the face of the hill. I could not measure the section; "neither could I trace the seam for any distance along its strike."

The Tándúr outcrops.

The next outcrop of Barákars is between Aksapur and Kasmi on the north or left bank of the Jángaom river; it is small, and there is no show of coal, but it is interesting as showing the extension of the Wardha valley deposits southwards. To the south of Jángaom, however, there is a long outcrop of Barákars extending from Kergúdem to Tándur in which coal appears at certain places; for these again, I must place extracts from Mr. Hughes' writings[1] before the reader:—

"The most northerly of these is one near Kairgúra.[2] The seam is seen in the right bank of the river that flows past the village in the direc-

[1] Rec. Geol. Sur. of India, Vol. XI, p. 20.

[2] Kergúdem of map.

tion of Chirákúnt,[1] a few yards north of the Tiráni road ghát. Only a portion of its total thickness is visible. Descending, the section is:—

	Ft.	In.
Coal	3	0
Carbonaceous shale	0	8
Coal	0	7
Carbonaceous shale and coal	...	

The dip is a little east of north, at an angle of 15°.

"In a small stream, east of the main river and tributary to it, a much clearer section of the seam is exposed, and its entire thickness is 15 feet. Most of it is coal, and much of it of fair quality. The average composition is, according to an assay made by Mr. T. H. Turner, the Assistant Curator of our Museum:—

Volatile matter (moisture 9·4 per cent·)	42·2
Fixed Carbon	45·6
Ash	12·2
	100·0

"Like the coal of the Wardha valley, and those of the several Godávari fields, there is a large amount of moisture in this sample. The fixed carbon is somewhat deficient, but the proportion of ash compares favourably with the standard for ordinary Barákar coals. Underlying the seam is sandstone identical with that which in the Wardha valley I have described as "nodular sandstone," and which always occupies a position immediately, or almost immediately (argillaceous shale sometimes intervening), under the coal. In the area that I am now describing, this kind of sandstone is constant in such sections as are exposed, and I would accept it as an almost sure sign of coal.

"The next outcrop of coal that I met with was about half-way between Kairgúra and Abápúr;[2] I look upon it as being the extension of the Kairgúra seam in a south-easterly direction. At the surface it showed a diminished section, being only 5 feet instead of 15 feet thick. It is probable, however, that, when sunk into, an increase will

[1] Charakota of map.

[2] About two and a half miles southward of Kergúdem.

be proved. The quality of the coal appears to be the same as that at Kairgúra, and it possesses the same tendency to split after exposure to the air for a short time.

"Another outcrop of this seam may be seen in the branch stream of the Guloti river coming from Abápúr. It is, as usual, near the top of the group, and is underlaid by very typical nodular sandstones. There is no other section in which the Barákars are so fairly exposed as in this one; and all the rocks are sufficiently characteristic to render their determination a matter of ease. The total thickness of the seam measurable is 9 feet. The direction of its dip is north-20°-east, and angle of inclination 11°.

"I met with no other outcrops of coal except the three mentioned above; but the fact that coal occurs, and is visible at intervals over a length of seven miles of country, makes it highly probable that it is continuous throughout the belt of Barákars from Kairgúra to Aknápali, To test this point, bore-holes may be put down anywhere near the junction of the Kámthis and Barákars, some allowance being made for overlap, for here, as in the Wardha valley, the former creep over the shore edges of the latter.

"From Aknápali to Tétmatla there are no Barákars shown upon the map. As I have already said, I am not prepared to maintain that they are absent, but I did not come across a single section which satisfied me that the rocks I saw were those of the Barákar group. Near Tétmatla there are sandstones which at first sight are somewhat difficult to discriminate from Barákars. In colour and texture and composition they are undistinguishable, but their method of weathering is different. They have rounded outlines, and they have lost the distinctness of their lines of stratification—a feature not usually observable in the Barákars, but common in the Kámthis: I have accordingly placed them in the latter group.

"Although Barákars are not seen, it is quite possible that coal exists, and I would advise sites near Sárángpali, Yenkatápúram and Tétmatla as being likely to prove successful in the event of borings for coal being

undertaken. In the river east of Tétmatla, about 500 or 600 yards above its junction with the Godávari, there are some very promising Kámthi sandstones, and a hole of 300, or at the most 400 feet, ought to strike coal if it occur.

"The only other remaining Barákars in the field that I could recognise occupy a narrow strip of country extending from Chinúr to Sandrápali. That these rocks are of Barákar age is testified by their well-marked lithological characters; and in the Godávari the nodular sandstone is a prominent and specific indicator of the group. The thickness of the entire series of beds is under 200 feet. There is no outcrop of coal, but the sandstone immediately under coal occurs at the mouth of the Sandrápali stream, and a boring in the right bank of the Godávari, a little below the union of the two rivers, will in all likelihood strike coal within a moderate depth from the surface. I found large fragments of coal in the bed of the Godávari opposite Pálgúla,[1] and I traced them up to within a mile or so of Sandrápali. This discovery was additional, and very satisfactory, evidence of the existence of coal somewhere in the neighbourhood of Sandrápali; and I have no doubt whatever that the site I have recommended for a bore-hole is a spot which, when tested, will justify the anticipations that my observations have given rise to.

Chinúr outcrop of Barákars.

"Two of the pieces of coal that I picked up I sent to the tahsils of Chinúr and Madápúr, to be deposited there and shown to such as might be interested in mining matters, and who would perchance pay a visit to Sandrápali on hearing of the likelihood of coal being found in the vicinity.

"Measuring as the crow flies, Sandrápali is only six miles from Sironcha, a station that, by the completion of the Godávari navigation scheme, would be brought into communication with the coastline of the Bay of Bengal. In the event of steamers plying up and down the river, it would be a convenient depôt for coal, with the advantage of being in British, and not foreign territory."

[1] South-east of Chinúr.

In the year after Mr. Hughes had found these traces of coal on the river, I also found further shows of coal fragments lower down the river, just above the village of Puspali.

Kámawaram and Bundalla.

Still, on this western side of the country, but many miles to the south, there is the small coal-field of Kámawaram, and not far east of it is the Bundalla outcrop,[1] which was discovered by Mr. W. H. Heenan, of the Hyderabad Public Works Department, when he was Superintendent of Borings. Since my report on the Kámawaram coal-field was published in 1872,[2] no further attempt has been made to develop it, mainly on account of its small extent, its difficulty of access, and because a better and more convenient field lies to the south, at Singareni. It will be enough here to reproduce my general estimate of the extent and quality of the coal.

The area is about 156 acres; there are two seams of 6 feet and 6 feet 12 inches respectively; and the amount of coal likely to be got out is 2,265,120 tons. The coal is half shaly and stony, the shaly being the best; so the amount of fairly good available coal may be further reduced to 1,132,560 tons. The high dip of the beds, and the large amount of water contained in them are great disadvantages; and then the country is far inside of the Pákál hills, very difficult to be got at, and unhealthy.

Coal on the Kinersáni stream, at Bundalla.

Concerning the Bundalla outcrop, or, as it is otherwise called by Mr. Heenan, the Bollapully (from a small village in the neighbourhood) field: in the first instance it was reported in 1872 that coal had been discovered by one of the Koi people (the tribe dwelling in this hilly region) in the hills lying some 16 miles east of Kámawaram. Mr. Heenan writes:—"The most direct route from Kámawaram to Bollapully, which is the nearest village to

[1] I am unfortunately not able to show this outcrop in the map. Mr. Heenan found the place long after I had left that part of the country, and I did not see his report on the coal-fields until much later. Thus, I can only indicate the locality approximately as being about two miles due east of the village of Bundalla.

[2] Rec. Geol. Sur. of India, Vol. V, p. 50.

the coal field, passes through a rough and hilly region, completely covered with forest, and thick low scrub jungle, and at intervals the path crosses very deep ravines, which render it dangerous for horses and quite impassable for wheeled conveyances of any kind. Upon leaving Bollapully which is about three and a half miles north-west of the hills where the newly-discovered coal exists, the path crosses the bed of the Kumersani river, and, passing over a couple of miles of broken and much disturbed ground, enters the bottom of a deep ravine, at the head of which the coal is exposed in a small cave, having about 70 feet of superincumbent sandstone forming its roof. The lower portion consists of the Damúda and the upper of Kámthi sandstones, with a thin layer of laterite at the surface.

"The summit of the hills which form the valley where the outcrop is exposed consists of a very extensive plateau, stretching far away to the eastward, with large detached masses of sandstone occasionally strewed about. Owing to the great difficulty of procuring water during the months of March, April and May, very few people reside in this region, and if this field should ever be worked great difficulty will be experienced in obtaining supplies and water. Where the outcrop of coal is exposed it is six feet in thickness, dipping to the eastward, at the easy angle of about three degrees; as, however, such a small portion of it is visible, and the rocks round about are much broken and disturbed, it was impossible to form any estimate of the extent of the seam; but since the carboniferous formation is everywhere exposed in the neighbourhood of the outcrop, it may prove to be very extensive, but, owing to the working season being far advanced, and many members of the exploring party suffering severely from jungle fever, it was found impossible to make a thorough examination of the neighbourhood."

It is most unfortunate, as far as my own work is concerned, that I missed this outcrop; but the fact is I never expected that such would turn up in a country which is manifestly very extensively made up of Kámthi strata, and more particularly as the Bundalla ridge on the west side of the valley is made up of eastward dipping beds the facies of which

both Mr. Hughes and I considered to be undoubtedly Kámthi. As it is, the Barákar strata must be brought in here by faulting, and Mr. Heenan's find is most interesting as showing the probability there is of coal being found here and there, though I fear at good depths below the great spread of Kámthi sandstones to the eastward.

Before this, in 1871, but many miles below, on the same river, Kinersáni, Mr. W. T. Blanford[1] visited the village of Alápali, where he had been informed that coal had been found; but this was only in fragments and no outcrop has as yet been met with near that village. I myself, in passing over this country the year afterwards, noted a likeness to the Barákar strata of Lingála on the Godávari, in the rocks between Alápali and Gúndalla, but I failed to find any coal outcrop. It is thus very probable, considering the coal outcrop occurring higher up the river at Bundalla, and that Barákar-looking strata occur as far down as Alápali, that a good outcrop or strip of the coal-bearing rocks does really exist in this part of the country, only such a wild region as it is will require the more close examination of a special exploring party; and, as it is in the Nizam's dominions and not so conveniently situated on the river as the Madaváram or Damercherla field, this can be very well delayed until the latter is proved by more extended borings than have been carried on hitherto.

The Singareni field.

The Singareni field, situated some sixteen miles south-by-east of Kámawaram, though very small, has the advantage of containing better coal, while it is a little more conveniently situated. There is only one seam of coal exposed; and of this only a small portion of the upper surface. Concerning the quality of the coal thus found, I wrote as follows[2]:—

"The coal, so far, is tolerably light, compact, charged slightly with patches of powdery charcoal, is more or less bright, and breaks with a sub-conchoidal fracture. In an open fire after being well dried in the sun, it burns brightly, though not quite so brightly as that of the

[1] Rec. Geol. Surv. of India, Vol. IV, p. 82.
[2] Rec. Geol. Surv. of India, Vol. V, p. 65.

Pangady Vagu (Kámawaram) field, and leaves a soft powdery ash. A fair average specimen gives the following assay :—

Fixed carbon	62·4
Volatile matter	22·6
(Moisture 6·0)	
Ash	15·0
	100·0

Mr. Heenan's account.

On my recommendation, a system of borings was carried out by the Nizam's Government under Mr. Heenan's superintendence, and he subsequently gave a general account of them in his general report on "Coal in the Deccan"[1] just quoted above, though I think it fair to state that he takes altogether too liberal a view of the results obtained. There is no doubt that the quantity of coal is large for so small a field, and that it is of fairly good quality; but it did not appear to me, when I visited the field again and inspected the bore sections, that there was always reliable recognition of the different seams met with in each bore-hole. The thick seam at or near the bottom was, so far, at that time not at all constant in thickness; it seemed to me to have a tendency to thin out rapidly within short distances, and to be, in fact, a pocket seam. Subsequent borings may have confirmed Mr. Heenan in his enthusiastic calculations, but I would deprecate any large expectations as to the probable amount of coal.

Four seams were struck and are supposed to be tolerably permanent throughout the field which is reckoned to be about eight square miles in extent. The field is divided into a northern and southern area, the former having been most explored by boring for depths varying from fifty to two hundred and fifty feet. The upper seam is composed of excellent coal, the upper half being hard and compact, and the lower somewhat softer and more bituminous. It has an average thickness of six feet, and Mr. Heenan estimates that five and a half million tons of workable coal may be got out. The second and third seams have an

[1] No. 160, Coal Fields Branch. H. H. the Nizam's Public Works Department.

average thickness of three feet each, and the bottom seam which is about 150 feet below the surface gives sometimes a thickness of thirty-four feet of solid coal.

Coal from the lower seam is said to give the following assay :—

Fixed carbon	66·0
Volatile matter	23·0
Ash	11·0
	100·0

A trial shaft was run down to a depth of sixty feet at 200 feet south-west of the outcrop of the upper coal seam; it reaches the bottom of the seam. About 300 tons of coal were excavated and carried by carts all the way, above 120 miles, to Hyderabad for experiment, when it was found to work very satisfactorily both in the stationary engines and at the forges in the workshops.

Attempt to use this coal in Madras.

About two years ago, at the request of the Duke of Buckingham, then Governor of Madras, a large consignment of this coal was carted down to Bezváda on the Kistna and then transported to Madras by canal as an experiment in the cost of carriage and for trial on the railway.

Of this consignment Mr. Trevethick, Locomotive Superintendent, Madras Railway, writes in his letter[1] to the Madras Government—

Opinion from the Locomotive Superintendent, Madras Railway.

"The trial had been made exactly in the same manner, with the same trains, men, and class of engines, and over the same ground, as the recent trials of various coals reported in this office letter No. 2624—484, dated 1st August 1878, so that a fair comparison can be made between the results of the two sets of experiments.

"Patent fuel is the most economical fuel (except wood) that we now have, and I have added, in the annexed form, the figures representing the results of the last experiments made with the patent fuel in order to serve as a comparison with the now tried Godávari coal.

[1] 4th December 1879, No. 3590-627 (Government of Madras, Public Works Department, 13th March 1880, No. 638 W).

"The figures show that the cost of patent fuel required to run the mail train 100 miles is at present prices Rs. 22-11-9, and to attain the same result with the Godávari coal its cost should not exceed Rs. 15-4 per ton stacked in the Rayapuram yard.

"There was no difficulty in maintaining steam with the Godávari coal, but it was found to make a great deal of ashes in the ashpan; it did not clinker much, but the accumulation of ashes in the fire-box at times became so thick as to check and almost stop the draught, and it could only be got rid of by raking out from below.

"The coal is very hard, makes little dust, and leaves very little ash in the smoke-box. It seems to require rather more air space on the fire-bars than other coals we have been using.

"This coal from the Godávari district is a good serviceable fuel, and if the facilities for carriage are such as will admit of its being delivered to consumers at a reasonable rate, it should be well worth working."

Remarks thereon by the Consulting Engineer to Government for Railways.

On this, and in the same papers quoted in foot-note, Colonel J. H. M. Shaw-Stewart, R.E., the Consulting Engineer to the Madras Government for Railways, makes the following remarks:—

"According to the memoranda from Hyderabad, the cost of the coal sent from the Singareni field to Madras was as follows:—

	Rs.	A.	P.
Cost at pit's mouth	8	8	2
Cartage to Bezváda	14	8	8
Boat to Madras	6	6	7
Cost per ton ...	29	7	5

"Had the coal been sent *viá* Rajahmundry the cost would have been:—

	Rs.	A.	P.
Cost at pit's mouth	8	8	2
Cartage to river	14	6	0
Boat to Rajahmundry	5	0	0
Transhipment	0	6	0
Boat to Bezváda	3	12	0
Boat to Madras	6	6	7
Cost per ton ...	38	6	9

"It is stated that the cost at pit's mouth was excessive, and that Rs. 6 per ton should be sufficient; also that, if a good road were available to Bezváda, the cartage hire would be reduced by Re. 1-8 per ton.

"The cost of conveyance by boat from Bezváda to Madras works out to about 4½ pies per ton mile; but, as shown in Proceedings of Government annexed,[1] the charge for coal conveyed in full boat-loads should not exceed 2 pies per ton mile, which for a distance of 274 miles would give Rs. 2-13-8 per ton.

"Making these allowances, the cost would stand thus—

	Rs.	A	P.
Cost at pit's mouth	6	0	0
Cartage to Bezváda	13	0	8
Boat to Madras	2	13	8
	21	14	4

to which must be added the cost of carriage to the Locomotive Department.

"In the demi-official letter from the Locomotive Superintendent, it is stated that, at present prices, Godávari coal of the quality experimented with recently would be worth Rs. 17-13-6, delivered in Rayapuram yard. For economical use it would be necessary, therefore, to still further reduce the price, as shown above, by Rs. 4.

"In the rate of Rs. 15-6-7, quoted in His Grace's note for Singareni coal, delivered at Madras, it is assumed that a tramway is made from the coal field to Bezváda, a distance of about 80 miles (72 miles in a direct line). Supposing coal to cost Rs. 6 placed in wagons at the pit's mouth, and to be carried at a rate of 8 pies per ton mile, the cost per ton delivered at Bezváda would be Rs. 9-5-4. Taking, as before, the cost of conveyance to Madras by boat at Rs. 2-13-8, the cost at Madras becomes Rs. 12-3. If this coal were used extensively, it would probably be found desirable to have a depôt on the banks of the canal near the Salt Cotaurs Station, so as to avoid further charges. Allowing for transfer from rail to boat at Bezváda and for contingencies, it is thought that the total cost of Singareni coal delivered at Madras should not

[1] Dated 2nd May 1873, No. 1257.

exceed Rs. 13 per ton, which is Rs. 4-13-6 within its comparative value at present prices of English fuel.

"The normal annual consumption of the Madras Railway is about 12,000 tons, equivalent to 16,000 tons of Singareni coal, on which the saving would amount to Rs. 77,500. This coal could also be used to a large extent by the South Indian Railway.

"Reference is made in the correspondence to a proposal to open out the Dumagudem coal field on the Godávari. The cost of supplying Madras from this point is fully dealt with in the Proceedings before quoted; it being shown that coal could probably be delivered in Madras at Rs. 10 per ton, *viz.*, cost on board Rs. 5, conveyance by boat 480 miles at 2 pies, Rs. 5."

Latest comparative value of Indian coal.

The latest information I have of comparative values of Indian coal and patent fuel has been kindly supplied me by Colonel R. H. Sankey, C.B., the Chief Engineer to the Madras Government:—

Kurhurballee coal costs—	Per ton. Rs. A. P.	It should only cost in order to compete with patent fuel—	Per ton. Rs. A. P.
At Madras ...	... 27 4 0	At Madras ...	... 19 2 0
„ Barákar ...	... 21 0 0	„ Barákar ...	... 16 7 0
„ Barákar ...	... 22 12 0	„ Barákar ...	... 16 3 0
„ Ranigunj ...	... 20 3 5	„ Ranigunj ...	... 14 13 0

Under present circumstances Madras cannot look to Singareni field.

Practically, the getting of coal from Singareni for Madras must wait until a tramway is built between the field and Bezváda, or, better, until a line of rail is opened up between Hyderabad and that town.

There then only remain the fields on the Godávari river itself, or the more southerly one of Beddadanol, to which further exploration can be directed, and this has been so far carried out in a practical way that His Grace the Duke of Buckingham has had a shaft sunk in the Madaváram field,[1] on the left bank, or British side of the Godávari, though

[1] The village of Madaváram is situated about a mile further down the right bank of the river than the village of Damercherla, which is given in the map. My error in not specializing the village from which the coal-field was named arose partly from the fact that Madaváram is not given in the atlas sheet from which this map is reduced.

as yet with very questionable results. At his instance, in July 1880, a corporal of sappers and fourteen privates were started to sink a shaft, six feet in diameter, at a point one-and-a-half miles north-west from Tiperpenti, on the left bank of the Godávari, some twelve miles below Bhadráchalam. The last reports, later in the year, showed that they had got down fifty-six feet with water coming in at such a rate that it could hardly be kept down by the pumps in use. I have heard since then that the work is at a stand-still until some qualified person can be found to take charge of the operation.

The Madaváram or Damercherla field.

This Madaváram field was examined and reported[1] on by Mr. Blanford in 1871, and the pit or shaft now sunk would appear to be in the neighbourhood of the stream which joins the river at the village of Ganaram or Tatpali, where most of the borings suggested by Mr. Blanford were put down. Mr. Blanford's report is rather long for reproduction here; but, as the question of the obtaining of fuel within any convenient distance has again, within the last month or so, been brought before the Government of India by the Secretary of State with reference to a letter from the Directors of the South Indian Railway Company praying that enquiry should be made into the prospects of coal in Southern India, I take the liberty of appending his paper as an appendix to this memoir. His general summary, taken from a manuscript memorandum on coal in the Nizam's country, dated 3rd October 1876, is as follows:—"Just below Bhadráchalam, the Godávari traverses a small field of Barákar rocks about seven miles across from east to west and five miles where broadest from north to south. The whole area is about twenty-four square miles, the greater portion of which lies on the right bank of the river in the Nizam's territory. The portion of this field on the north (left) bank of the river has been thoroughly explored by boring and some coal has been found, but the quality is altogether inferior, and the quantity small, the seams being thin and much mixed with shale. The examination of the tract south of the river by boring was stopped by order of Government. Although the prospects

[1] Rec. Geol. Surv. India, Vol. IV, p. 59 *et seq.*

are poor, it is highly desirable that this field should be thoroughly explored, because it is situated on the navigable portion of the Godávari below the first barrier, and any coal found could be transported easily and cheaply to the coast."

Poor on British side of river.

There is after all only a small quantity of coal, at the most liberal computation, on the British side of the river, about 25,000 tons, of which quantity, according to Mr. Blanford, it is as well not to assume that more than one-half can be profitably worked; and, except as an encouragement to the Nizam's Government to open up on the other side of the river, or as a source of local supply of fuel to the Dowlaishweram works below Rajahmundry, I cannot myself but think that the sinking of the pit is hardly to be commended.

On the Nizam's side of river.

Mr. Blanford's trials.

The hope remains that more and better coal may be found on the Nizam's side of the country. As it is, Mr. Blanford arranged to put down fourteen bore-holes near the river bank; but only six of these were carried out, and then, owing to some misunderstanding, they were stopped by order of the Government. Mr. Blanford remarks that "the borings, so far as they had been carried out on the right bank, had shown the existence of sandstones and shales similar in every respect to those seen on the bank of the river, except that in two or three instances small fragments of coal, proving the existence of very thin seams, probably not exceeding two or three inches in thickness, had been brought up by the borer. These little seams, although absolutely worthless in themselves, are of importance, as indicating that the mineral does occur in the beds, and that hopes may be entertained of larger seams being found."[1]

Borings of Messrs. Heenan and Taylor.

Subsequently, a further examination of that side of the country was made by Messrs. Heenan and Taylor of the Nizam's service, in 1874, and, though they were not able to find any outcrop of coal *in situ*, the borings put down by

[1] Rec. Geol. Surv. of India, Vol. IV, p. 61.

them proved clearly that good seams of coal do exist in the field. They selected an unbroken area in the great tract of Kámthis situated three miles from the large village of Raigúdem and five miles south of the Godávari, of about five miles in length and two to three in breadth. Three seams of coal were discovered, the first of which lies below a compact mass of hard whitish sandstone at 247 feet from the surface and is one foot thick. The second seam of four feet thick is at 272 feet; and the third seam, which is six feet thick, was struck at 314 feet. The quality of the coal is not definitely stated, but it seems to have been rather inferior.'

Before leaving the tract it is necessary to notice a small inland patch of Barákars which occurs about eighteen miles to the west-south-west, near the large village of Chundragunda. No coal was found here, but the rocks have an unmistakeable Barákar look, and I have long looked on this as a favorable indication of the extension of the Madaváram or Damercherla coal-field underneath the wide stretch of Kámthis forming the Dummápet hills.

Lingála outcrop.

The only other river outcrop is that of Lingála below the mouth of the Tál tributary. Of this Mr. Blanford writes—

Mr. Blanford's account.

"Of the seams found, two, neither of them exceeding two feet in thickness, were detected close to the left bank of the river opposite the village of Lingála. The quality of the coal is rather inferior, and both seams thin out and disappear within a few yards; moreover, as the dip of the rocks at Lingála is towards the river bed or south-west, and the outcrop exactly parallel with the bank, it is clear that the beds, even if of good quality, could not be easily worked at this spot, as the whole of them within any reasonable depth must be beneath the bed of the river.

"The third seam found crops out in the middle of the river bed; it is about five feet thick, and the quality appears better than in the other seams. The reef of sandstone resting on this coal can be fairly traced at

[1] Coal in the Deccan, *op cit.*, p. 20 *et seq.*

intervals for some distance; and, after running along the river for about a mile, it turns in towards the right or south-west bank. Here its course becomes obscure. Borings were put down by Mr. Vanstavern near the spot where the coal would probably crop out on the bank, but without success. Another thin seam, only two feet thick, has also been detected by Mr. Vanstavern on the right bank of the river. This, like the two first met with, thins out within a few yards in one direction."

Being examined by Mr. Taylor.

I myself passed down here last year (1880); and this is still about all that is known of this field. It really lies, if of any extent, on the Hyderabad side of the river; and when I passed, it was about being examined by boring, by Mr. Taylor; but nothing had been done then that I could hear of. The country is very much covered up by superficial deposits and the river alluvium, or by jungle, and is very wild and thinly populated, so that I expect it will be some time before any satisfactory observations have been made; besides, I do not expect it will be otherwise than a small area. It would be much better if all the mining resources of the Nizam's Department of Public Works were devoted, at first, solely to the examination of the southern portion of the Madaváram field.

Lastly, there is the Beddadanol field, the most southerly outcrop of Barákars known in the Madras Presidency, in which I once had every hope that a fair quantity of coal might have been found; but, as already noticed, the borings which were carried on under the superintendence of Mr. T. Vanstavern (then Executive Engineer at Dummagúdem) only showed some thin seams of very poor coaly shales, and then, as there seemed little chance of better results in British territory, the exploration was abandoned. Had we only received the faintest encouragement in the way of better coal in any of the seams as they were pierced in different parts of the field, I should have pressed for extended and deeper boring through the superincumbent Kámthis to the south-west; we had also got, to all appearance, to the floor rocks, and thus no hope lay in increased depth which is what many people believe in, while it also thus appeared that the Barákars might

The Beddadanol field not promising.

chimney is made of a grey clay with which is mixed a good deal of paddy chaff or rice husk. The hollow of the furnace itself and the lutings are of brown clay. The front of the furnace is closed up by a shield already prepared and made of clay, or of lumps of the old slabs, and dusted over on both sides with powdered charcoal. The charcoal dusting is said to prevent the shield cracking. The shield is luted up against the open wall with clay, a hole being left near the bottom for the blast from the bellows. I could see through this hole that a good, nearly white heat had already been got up on the floor of the furnace The bellows were then fixed, and blowing commenced, the iron nozzles of the bellows being placed just at the mouth of the hole at the bottom of the slab; no tuyeres were used, and there is no luting up or otherwise of the aperture round the nozzles. From time to time, a stick is thrust into this aperture to stir up the interior, when there is a rattling down of the material in the upper part of the furnace, and a flare-up of red flame and sparks at the mouth of the chimney. The chimney, or rather the pot or funnel of it, was, in the first instance, heaped up with charcoal. When the charcoal is sufficiently consumed for the contents of the chimney pot to have fallen down a few inches, a small basketful of ore is thrown in on the top; and after this ore had disappeared and the pot of the chimney is half-emptied, a further similar supply was thrown in, and the pot then piled up with charcoal.

And so the process went on, further supplies of ore and charcoal being thrown in to the extent of about forty baskets of ore of about 160 seers or pounds in weight altogether, and I should say about eighty baskets of charcoal. This smelting commenced about 5 o'clock in the evening, and it was said to go on for half the night, or say seven hours. After about two hours, the first cinder or scum is drawn from the side vent, and, altogether, this vent is tapped about nine times during the operation. The supplying of the ore is stopped about the fifth hour. At the end of six or seven hours water is thrown on the front, or luted-up shield, which is then broken away, and a mass of pasty seething metal is disclosed in the bottom of the furnace.

The metal is then stirred about with big sticks until it becomes sufficiently solid to be hauled out of the pit with a large pair of tongs, is beaten a little, and then subsequently balled and refined on the refining hearth. For this last process the coarser bloom is broken up all over its outer surface, then balled up among ashes and bits of slag, exposed to a good heat in the open hearth, and beaten with heavy mallets. The crude iron resulting weighs about fifteen seers or pounds, and this is handed over to the merchants or their agents for Re. 1-4 (usually in grain or food) and sold afterwards in the bazaars up and down country for Re. 1-12 or thereabouts.

The manufacture is only carried on during the dry weather, and then only according to the demand. The iron is afterwards forged up into small bars and used for all agricultural implements; and even for the tires of the small cart-wheels of the country, though English iron is preferred for these as soon as ever it can be brought within reach of the people.

Gold.—There is a general idea that gold is washed for at the mouth of the small tributary of the Godávari near Mangapet; but all my enquiries regarding the washings and the amount of gold obtained resulted in disappointment. The only information I could get was that the sands at the river mouth used to be washed some years ago, but that the people who did so came from a distance at the end of the hot weather, and were not to be found now. Much of this insufficiency of information, or perhaps unwillingness to give it, was in part due probably to the fact that a new tahsildar had just arrived at the place, who either could not get the information, or would not trouble himself to do so. He said there were no records in the cutcherry or office having reference to the subject. The amount of gold obtained, or said to be obtained, is the usual two to four annas worth a day, of which we hear in every gold region of Southern India.

Supposed occurrence at Mangapet.

Not having myself been able to refer to such authorities as exist, I am indebted to my colleague Mr. V. Ball, at Calcutta, who kindly sought out the following information for me:—

"The occurrence of gold-dust in the bed of the Godávari has long

been known, and mention of it is found in several works published about the beginning of the century.[1]

"According to Dr. Walker[2] there was a gold mine about the year 1790 near the village of Goodloor or Godalore, where the Kummummet and Ramgir circars meet, which had been profitably worked by the Paluncha Raja. At the time of his visit he could hear nothing locally of this mine, but learnt that washing had been carried on comparatively recently in the streams which feed the Godávari from the south. It was the custom to place bunds across the streams and after the rains had ceased to wash the sands so arrested. The washers belonged to a peripatetic race, who were employed by a rich Baniah. Owing to an excessive rent charged by the Raja, operations ceased and had not been resumed.

"At Marigudem the gold is really brought into the Godávari by streams in Hyderabad territory; and, in fact, this Godalore must have been near to, and derived its gold from, the same sources as Marigudem. As there are no crystalline rocks in the neighbourhood, it is improbable that there ever was a rich mine here."

The Marigudem mentioned here is on the opposite bank of the river; and Mangapet is really the proper village. Mr. Ball further writes in reference to the gold being washed for in a small stream opposite Marigudem. "It is washed by people called Sonjharis (*lit.* gold-seekers) not Sunjerries as it is sometimes written, who come periodically for the purpose. They begin operations in August or September or whenever the river has fallen sufficiently to lay bare certain gravel banks in which the gold occurs in minute grains. The gold is of superior quality to that of some other localities, being valued at Rs. 16 a tola."

Rocks unfavorable.

The strangeness of this locality is that there are no crystalline rocks exposed on the Mangapet stream drainage area, which is all in sandstone of Kámthi age; so that

[1] Oriental Repertory, Vol. II, 1808, p. 472; Materia Medica of Hindustan by Sir W. Ainslie, 1813, p. 54.

[2] Madras Journ. Lit. and Sci., Vol. XVI, p. 183.

the dust must either come from some of these sandstones themselves or from quartz pebbles of these conglomerates; or else, which is hardly possible, it may be brought from higher up the Godávari with sands which are here piled up around the mouth of the tributary.

Rather a gold merchant's village.

I am more inclined myself to look on the talk of gold occurring at Mangapet as arising from the fact that this place has from time immemorial been a very convenient residence for gold merchants, it being situated on the one route up the river valley, and at the river end of one of the few tracks leading to Hannimkonda and Hyderabad.

PART 2.

CHAPTER IV.—THE GNEISSIC SERIES.

Schistose and Massive Gneisses.—These bottom or floor rocks form either side of the great valley, the superincumbent formations covering portions of the middle area from end to end of the field; but, about Dummagúdem the latter are so narrowed by denudation that the crystallines of either side of the country are brought sufficiently close together to allow of a crude boundary being recognised between the very different styles of gneiss which characterise the Hannimkonda or Nizam's side of the country and the British or Bastar side.

In a previous memoir[1] I have adopted the following classification of gneisses, which to a certain extent is also applicable to the crystallines of this region :—

Classification.

Schistose Gneisses	...	Micaceous, talcose, and hornblendic schists, with few quartz schists or quartz-rocks. Foliated gneisses, with frequent quartz-schists or quartz-rocks.
Massive Gneisses	...	Grey gneisses (sometimes porphyritoid). Red granitoid gneiss.

[1] Mem. Geol. Sur. of India, Vol. XVI, part 2, p. 16.

Here, too, the *massive gneisses* constitute the Hyderabad side of the country, while the Bastar territory is made up of a decidedly more foliated and nearly schistose set of rocks. At the same time, though we have here a series of gneisses which are a northerly extension of the Nellore and Kistna crystallines, there is not, in so much of the Bastar country, a representative of the very schistose rocks of the Nellore district. There is an addition, however, of a more compact form of gneiss which has not hitherto been met with in any force in South India.

Northerly extension of the Nellore and Kistna crystallines.

In connecting the rocks of the present field with those of the Carnatic districts by what is known of the rocks of the intervening portion on the Kistna river, it would appear that the micaceous, talcose and hornblendic schists of the Nellore district have thinned or died out entirely in the Kistna district, while the main body of the older sub-division of the *schistose gneisses* is continued on up into the Godávari field. The portion south of the Kistna has been described[1] by my colleague Mr. Foote.

On the north or left bank of the Kistna, Mr. Foote's middle belt of granitic gneiss (see Fig. 1 in the memoir cited) is continued in the Kondapili hills, a strong massive hornblendic gneiss often garnetiferous, well foliated and bedded; and on either side in the plains below are the more foliated gneisses of the schistose family. So far along the bank of the river, that is, from near Bezváda as far west as the Pallér river near Battavol or Jaggayapet, these gneisses are prevalent, and they strike off from here northwards. On their eastern side they are flanked by the belt of murchisonite gneiss of Bezváda, which trends away north-north-eastward to Vizagapatam. I am not able to write so definitely of the crystallines on the western side; but it is certain that they approach more and more to the red or granitoid gneiss of the massive division, as occurring in the neighbourhood of the city of Hyderabad.

In the intermediate area of the Kistna.

[1] Mem. Geol. Sur. of India, Vol. XVI, part I. In this memoir Foote uses the term granitoid in a different sense to which I myself have applied it; here his granitoid gneisses are hornblendic according to the modern view of the composition of granite, whereas I have, as of old, called these syenitoid gneisses.

Southern extremity of field.

At the southern limits of the present tract, the hornblendic gneisses of the Kondapili hills come in near Maidúr Gut by the smaller range of Anamalanka, having a north and south strike in the foliation and a dip of about 70° to the eastward; and from here they are continued, but with frequent detours from the normal strike, and less persistence of the more hornblendic varieties, to the next hill mass of Kannigiri. In the intermediate country the rocks are very varied, well foliated, and sometimes decidedly schistose, generally rather coarsely crystallised, quartzo-hornblendic, the hornblende being in strong laminæ. Eastward of Anamalanka the rock is more quartzose and, as in the Pútrála ridge, there are a few strong bands of quartz-rock or quartz-schist approaching almost the character of quartzites. A couple of miles further east, micaceous rocks come in with more schists; and a few miles still further east, in the Kandaparawa ridge, but without any close boundary, the red murchisonite, garnetiferous and schistose gneisses of the Bezváda group[1] are prevalent. A few miles north of this, a traverse on the route from Kummummet to Ashwarowpetta shows that the gneisses are still much the same, but they are now beginning to curve round in a north-west to south-east strike, having for the most part a high dip to the eastward.

Separation between the two gneisses.

At Kummummet massive grey quartzo-felspathic gneisses come in on the western flanks of the more foliated rocks of the Kanijirla, Kullúr, and Maidúr Gut country; hence I would separate the schistose gneisses from the massive varieties just about here or nearly half-way between Kummummet and Kanijirla, whence the former trend off rather to the north-east towards the proper Godávari valley.

Strips of Kadapah rocks.

Also, here, at this boundary, there are several obscure bands of sub-crystalline limestone associated with quartz-schists or, as I believe them to be, highly altered quartzites, which may as well be noticed here, though they are not clearly belonging to the gneiss series. They are, in fact, connecting strips of the

[1] See Mem. Geol. Surv. of India, Vol. XVI, part 3, p. 12.

upper transition series, left here and faulted in among the gneisses; very poor remnants of a patch which once probably connected the Kistna and Pákál fields of that formation.

Still keeping to the foliated or schistose division of these rocks, as they occur a few miles beyond Kunijirla, the strike of the foliation is diverted from its usual more northerly and southerly course round to the northward for some miles, past the large hill mass of Kunnigiri, after which a north-east strike is again assumed and carried on up the wide valley between this hill and the lower Yenkatpur ridges on the western side, until the series becomes overlaid by the Kámthi sandstones of Pálúncha.

The Kunnigiri hill.

Kunnigiri hill is made up, as might be expected from its standing out here in all its boldness of 2,000 feet in height over the Chundragúnda plains, of more massive and thick-bedded gneisses, very similar, in fact, to those of Kondapili hill further south. Though the intervening rock area of low country is much covered up by superficial deposits, and outcrops are rare and widely separated, still I feel sure that there is no important occurrence of the Kondapili beds; so that these two hill masses appear to be the last swellings-out of this particular group of hornblendic gneisses preparatory to the final thinning-out of the group northwards, there being no further strong show of such in the Bastar country.

On the eastern side of Kunnigiri, on which the lowest beds are seen, the dip being from 40° to 60° to the south-west, the rocks are hard schistose and well-laminated garnetiferous quartz-rocks, grey hornblendic gneiss, and dark hornblende schist with thin bands of quartz-rock crowded with good red garnets, which weather easily into brown iron ore. Garnets occur also scattered through both the hornblendic and quartzose gneisses, but the larger ones are generally in the more crystalline quartz-schists, which every now and then thicken out in nodes and purses. There is also a massive flesh-coloured felspathic variety of the gneiss, occasionally in rather thick beds. Still higher up, the pagoda ridge is of fine, hard, massive beds of grey, very dark grey, white, flesh-

colored and banded gneiss, much laminated with garnets, and seamed also with quartz segregations containing these stones. It is from these massive grey beds that all the huge blocks which were used for the old Telingána fortifications of this place were obtained.

Garnetiferous and kyanite gneiss.

The whole hill mass is made up of beds of this kind, being thus very much like the Kondapili range, though the latter consists, perhaps, more largely of the true hornblendic or syenitoid form of the gneiss. In both ranges the garnetiferous character of the rocks is very marked, and the low country adjacent to both has been for ages known for its production of garnets, these stones being very much affected by the poorer Muhammadans. To the north of Kunnigiri about Garíbpet, where the same rocks are more freely weathered or decomposed, and where they are also more schistose, garnets and kyanite crystals are very common, the former being still carried away in large quantities by contractors, who, however, only visit the place at long intervals.

There is also a good deal of schorlaceous gneiss associated with the hornblendic varieties, the quartz segregations and laminæ being crowded with small and large masses of black tourmaline, much in the same way as is the case with the seams in the garnetiferous gneiss.

Going west-north-west from Garíbpet, the massive gneisses are gradually passed over until, beyond Mútialpád, the more schistose rocks come in as northerly extensions of those at Kunijirla and Kullúr; and, nearer the Yenkatpur promontory of the transition rocks, these are succeeded by quartz-schists. Immediately north of Pálúncha they appear again in the proper valley of the Godávari and its affluent the Kinersáni river, whence they stretch away north-east into the Bastar country, forming the eastern side of the field.

The change in the gneiss on the Bastar side.

They are still very much the same rocks, grey felspathic and hornblendic gneisses, for many miles, until north of Cherla when there is a decided change in the constitution and aspect of the series, probably in part owing to the

presence of dioritic and other intrusive rocks, which are, with the gneiss itself, frequently and most profusely seamed and ramified by sharp veins, dykes and strings of fine red felspathic and pistacite granite. The gneisses are usually very hard and compact finely laminated hornblendic rocks, or else more varicolored and speckled rocks with the hornblende and grey or greenish felspar plainly distinguishable. The foliation and bedding are still very distinct, but they gradually bend round to the north-north-westward, though still having the usual easterly dip.

In the Bhopalpatnam country.

About Bhopalpatnam, or in the Indrávati valley, there is a further change to yet compacter and finer grained rocks, which almost assume a porcellanic texture at times, while the profusion of red felspathic and pistacitic veins is remarkable. This portion of the Indrávati flows for many miles in a wonderfully rocky bed, the main channel being—especially above Bhopalpatuam where the river flows for short distances across the strike of the beds—often a straight canal cut clean through the hardest and compactest rocks, a form of bed which is quite exceptional in the gneiss country and evidently due, for the most part, to the peculiar constitution and character of the rocks, which so far appear to form a peculiar variety of the gneissic family.[1] The same kind of rocks are continued north-westwards by Ahiri, and so by the valley of the Pránhita and Waingunga into the Chánda country, the beds of these two rivers being also as rocky as that of the Indrávati.

The gneiss of the Hannimkonda side of the country.

Returning now to the Kummummet region where we left the line of demarcation between the *schistose* and *massive gneisses*; the massive grey gneiss can be traced thence by Hannimkonda alongside of the western edge of the transition and Vindhyan rocks of Pákál and the Upper Godávari reaches. This is generally a coarse aggregate of quartz and one

[1] I have already seen very much the same style of gneisses in other parts of southern India, but only at rare intervals, and then merely as local bands of small extent, the most marked of which is on the Chittravati river near Párapali in the Bellary district and on the western edge of the red or granitoid gneiss. Here also the presence of red felspathic and pistacite granitic veins was very marked.

or two kinds of felspar and some hornblende; but the gneiss of Kummummet hill fortress and the other large humpy masses which stand out on the low country is more properly an exceptional variety of this division of the crystallines, being a finer-grained and compacter rock with very little hornblende in its composition, in which the foliation is not so well developed.

General sameness of character.

Throughout the whole of the western belt there is very little variety in the gneiss as a whole; every now and then local variations are common over short distances and will, no doubt, eventually reward close research into the character and composition of the divisions of the gneiss family. There was no time or opportunity for much detailed work in the present survey, and the general character of the rock is as I now describe it at certain points over the area. The Múniér river in its course north of Kummummet flows with the strike of a belt of coarse-weathering gneiss, largely crystallised and granitic looking, of red and white felspar dark-green mica and some quartz; foliation not clear. On the western side of this same valley there is also, for a good part of its course, a band of very rough-weathering coarsely crystalline dark grey gneiss or granitoid gneiss in which occur every now and then largish pieces of hornblendic and micaceous schist. The general look of this rock is that of a heavy conglomerate or breccia which has been highly altered. The enclosed fragments are arranged in a sort of north-north-west strike, dip, if any, undulating westward. About Pedda Gúdur there is still the same rock, very granitoid but distinctly foliated north-north-west to south-south-east, dip 45° to 60° eastward.

Conglomeratoid gneiss.

So to Gárla, but eastward of that village about Singareni, the schistose gneisses come in again and are very strong between that and the eastern promontory of transition rocks. In fact, the demarcation between the two gneisses which I distinguished between Kummummet and Kunijirla is continued up here and runs with the Singareni tributary of the Múniér.

Westward of the band of gneiss with enclosed fragments of schist, and on the route from Kummummet to Hannimkonda by Bíravoil, Narsingarowpet, Gúratúr and Katrálla, there is still very rough weathering and coarse grey gneiss of quartz felspar and some hornblende. The hornblende is, however, often replaced by dark-coloured bronze mica. The felspar is always the predominant mineral, is generally of a grey or white colour, in rather large crystallised masses. Foliation as usual north-north-west. About Bíravoil the gneiss is hornblendic to a slight extent, rather conglomeratic-looking at times with lumps or irregular and suddenly stopped-out masses of a finer grained and harder gneiss.

Trap dykes.

The country is traversed, in the neighbourhood of Bíravoil and Narsingarowpet by many large dykes of compact greenstone, though these do not appear to be very continuous in their course for any distance. About the former place there are two sets of dykes running north and south, or again rather east and west, the former being sometimes porphyritic with large crystals of pale-green felspar.

At Hannimkonda.

The generally uniform character of the western belt of coarse grey gneiss ceases in the neighbourhood of Hannimkonda. Here a rather more varied association of gneisses is prevalent, though these are still essentially massive and rather granitoid in their character; and this is also indicated by the more broken hilly style of the country, Hannimkonda itself being situated at the base of a group of rugged and rather humpy masses, the highest of which is about 600 feet above the plain. The country to the eastward and southward is mostly undulating with wide stretches or downs of tolerably bare and smooth rock surfaces among wider sandy and sterile soda soil plains much broken up by smaller knolls and groups of outstanding boulder-like masses. The long stretches of rocky surface are also at times broken by odd groups and tor-like masses of the more compact and finer grained rock standing out on their surface.

The Hannimkonda rock is essentially felspathic, with two felspars of

grey and red colors; and associated with it are bands of a more compact red rock, like a fine granite. Foliation is very indistinct, scarcely to be recognised; but there is this banded arrangement of the different textured rocks which has a north-north-east strike.

North-eastward of Hannimkonda and Warungul and so alongside the transition series, the gneiss gradually becomes more hornblendic in its constitution and thus more syenitoid in its character as opposed to the redder granitoid style of the gneisses which make up most of the country to the westward of these towns.

CHAPTER V.—THE UPPER TRANSITION SERIES, KADAPAH FORMATION.

Pákál quartzites, slates, &c.—This tract of rocks is entirely separated from the proper one of the Kadapah[1] series to the south, in the Pennér and Kistna basins, by a portion of the Kistna valley which lies between them for a space of some forty miles and is made up solely of crystalline rocks. The northern extremity of the latter field ends abruptly with a faulted boundary on its eastern side and a natural one on its north-eastern edge at Báttavol or Juggayapet, a short distance north of the left bank of the Kistna; and beyond this, there is the intervening tract of gneisses until about the parallel of Kummummet where the first traces of the northern field are shown by a narrow strip of sub-crystalline schistose limestone associated with highly squeezed quartzite which is still left wedged in among the rocks of the gneiss series. Then, some eight miles further north-east, the southern extremity of the present field is formed by the Yenkatpur ridges, whence it spreads out northwards over the great valley, but flanked on either side by the gneisses of Hannimkonda and the Bastar country. On the west side of the valley, there is a wide belt of these rocks constituting the hilly country of Pákál as far north as the Manér tributary of the Godávari, where they cease for a time or disappear, being overlapped by

Northern, but separate extension of Kadapah field.

[1] See note on p. 16.

strata of probable Vindhyan age. They show again some miles north of the left bank of this upper reach of the Godávari, forming the hill ridges right up to the Jángaom valley, where they are overlapped by Deccan traps; and, beyond this, they occur again in the Wardha valley.

Easy lie of the beds on western side.

As in the proper Kadapah field, here, also, the western and lowest beds of the series are lying easily, except at the southern end about Singareni, on the Hannimkonda gneiss, sometimes presenting low scarps to the westward and dip-slopes to eastward, while higher and higher strata are cropping up among and on the sides of the inner parallel ridges of the Pákál hills. There is, however, a good deal of folding and undulation, though the general dip is eastward.

Except at the southern end.

The easy lie of the bottom and edge beds on the gneiss ceases at the south end in the ridges east of Garla, or in the curiously rugged boundaries about Singareni which are all just the result of denudation among much folded and squeezed strata that have become at the same time so much altered and intimately associated with the gneiss that in many places they can hardly be distinguished from rocks of that series.

Faulted edge on the east.

This crushed-up and highly-altered condition of the beds is also continued east-north-eastwards across the Godávari by the Mámla range and so to Cherla, beyond which there is again a wide display of the series, but now remarkably easy in their lie, in the grand plateau hills of Albáka. However, at the northern end of this range, or just above the Indrávati junction with the Godávari, there is again a great deal of folding and disturbance displayed in the Sironcha hills, where, too, there is rather a wide extent of the series, though this becomes suddenly narrowed on the Prânhita by covering-up Vindhyans; and then, further north, the transition rocks are finally cut off and broken up into thin strips by a system of faults which stops off the eastern spread of all the post-gneissic deposits of the field at the Wain Gunga tributary of the Prânhita.

Intimate association of the gneiss and the Kadapahs.

The parallelism of strike of the outcrops in the Singareni or Yenkatapúr promontory with that of the gneiss, on the eastern side, is remarkable; and when to this is added the fact that both the gneiss and the transition beds are very highly altered and crushed up in this part of the country, it is difficult to avoid the conclusion that both series must have been thus metamorphosed and brought into such intimate contact by some great and unusual movement of the earth's crust, the direction of which was from the eastward. It is, indeed, owing to this altered condition of the junction or passage beds that the boundary is exceedingly obscure, and in point of fact has been drawn approximately on the lines shown in the map; while it must be eminently a faulted one. The separation of the crystallines from the Kadapahs is more clear to the north of Cherla and along the eastern side of the Albáka range; but there is still sufficient abruptness of the latter against the former to show that the faulted boundary is still continued on this side. The effects[1] of this old earth movement are entirely confined to the gneiss and the Kadapahs, and must have occurred long prior to the deposition of the Gondwána series.

Further probable faulting along the western side of Albáka hills.

At the same time, the rocks of the Mámla hills and Singareni are so different in their condition of alteration, in their strongly crushed-up and vertical position, and in their lithology from the easy lying quartzites of the Albáka range, while the change from one to the other is so rapid, or the interval between them so short, that I cannot but think there must be another great or strong line of faulting running up the line of the Godávari bed and separating the two fields of the Pákál and Albáka rocks from each other. That, in other words, the southern portion, though so violently crushed up and altered, still remains a part of the Pákál area; while the eastern or Albáka country was really disconnected and faulted down into its present position of easy lie between the gneiss of the Bastar side and the Pákál field. This view receives some confirmation

[1] The Sullavais or presumably Vindhyan rocks were apparently also affected by this movement.

from the fact that at the second barrier of the Godávari, at Enchapali, an outcrop of strongly folded, tilted up, and altered quartzites is again met with running northwards through the Sironcha country and corresponding in every way with the conditions of the Mámla outcrops. Of course, it is quite possible to conceive that the crushed-up quartzites slates and limestones of Enchapali and Sironcha are just the squeezed-up and folded strata of the lower portion of the Albáka range; but the change is altogether too sudden and violent at the Indrávati to have been brought about without fracture as well as crushing up.

The rocks have a Kadapah facies.

I have unhesitatingly classed these Pákál transition strata as of the Kadapah series, because, although they are well separated from the typical area, there seems no valid reason for looking on them as of any other known formation in India. They are associated by the same very decided and remarkable system of movements and metamorphisms which were exhibited at a particular period in the foundational rocks of the Peninsula; they are, to all appearance, lithologically identical; and, on the very face of the map, they are just a northerly continuation of the great field of the Pennér and Kistna basins.

Two groups like those of Kistna and Nallamallay.

It is, however, not at all so easy to correlate the sub-divisions of these rocks with groups of the Kadapah series, though in very many respects these answer to the Kistna and Nallamallay groups, the former being more particularly represented by those of the Pákál area, while the latter appear to have their likenesses in the Albáka beds. The strata of the Pákál side are mainly quartzites (altered sandstones) of various kinds, just as they are in Albáka, but they are distinguished as a series by the presence of some strong bands of limestones; at the same time, I would rather not force such a sub-division of the series, as much of the apparent difference in the character and constitution of the beds may be due to different alteration, as well to unequal exhibition of the rocks in the two fields, while great changes in the style of the strata are possible in such wide lateral extension.

The more altered rocks of the southern region.

The Singareni region, as already stated, is that in which there has been the greatest amount of crushing up and folding, and here there is presented the most varied selection of the rocks which are, however, considerably altered or changed from their normal style of easily recognizable quartzite conglomerates and sandstones, clay slates, and compact grey or fawn-colored splintery limestones.

The Singareni neighbourhood.

Bottom quartzites.

The lowest and bottom beds are nearly always coarse sandstones with some pebbles, which every now and then become very heavy conglomerates, as to the east of Baiaram; the pebbles being generally of quartzite and slate, scarcely ever of gneiss. Here, the boundary is a natural one, and bottom beds are recognisable lying on the gneiss; but in towards and round about Singareni, the junctions are nearly always very abrupt, and very often the gneiss is in contact with slates and even limestones. Indeed, it certainly looked to me here very often as if the original bottom, or floor, had been very uneven; and that here there had not been much depth in the waters in which these Kadapah strata had been deposited. Thus, the different beds which in other parts of the field are spread out evenly for great lengths of strike had here thinned out rapidly over one another and so shored on to the gneiss bottom; while this association is only rendered more abrupt-looking by the subsequent crushing up.

At any rate, so it is that heavy conglomerates, coarse sandstones, subcrystalline limestones, talcose slates, and quartz-schists are here found indiscriminately in abrupt contact with easily recognisable gneiss; or they are, most of them at times, so highly altered that it is difficult not to look on them as members of the more schistose varieties of gneisses.

Limestone bands and schistose or slaty beds.

Eastward of Singareni, quartzites and quartz-schists are strong, and the former at the bottom are very coarse granular felspathic beds with the red felspar fairly crystallised out among the quartz grains. With these beds are rare bands of compact grey silicious limestones. To the north-east and east-north-east

the first ridges are of laminated quartzites, much fractured or split up by a north and south cleavage, with quartzose slates; and associated with these are frequent narrow outcrops of limestone, grey and sometimes white, becoming rather saccharoid, and occasionally quite coarse and granular crystalline. The limestones are always much more contorted and twisted in themselves, as is shown by the frequent laminæ of mica, actinolite and silicious matter. This narrow belt of limestone outcrops in the ridges east of Singareni, runs away with the quartzites to the north-west.

Appears again round the Chídammulla, inlier of gneiss.

Further east, beyond the Chídamulla inlier of gneiss, there is again a very strong show of grey silicious limestones among the quartzites and slates, which are quite crystalline and strongly laminated with tremolite and actinolite in beautifully radiating fibrous and acicular bands and nests of several inches in thickness. These limestones constitute a wide belt, which is repeated probably by undulation and folding in the Yenkatapúr promontory stretching down towards Kummummet; and they present always the same highly altered character. Indeed, the Chídamulla inlier is a sort of nucleus around which this set of quartzites and limestones is striking, and it is fully evident that they are all part and parcel of one and the same band which runs away northwards past the Pákál tank.

Second and upper limestone band.

Still further north-eastward about Anantáram, and close under the western edge of the Kámthi sandstone, there is another broadish band of limestone of much the same kind, saccharoid and laminated with tremolite. The difficulty is to decide how many separate limestone bands are here represented in the Singareni region; there are so many broken outcrops, and the rocks they are associated with are very similar. While the lowest beds of the series must be tolerably well represented all round the Singareni bay of gneiss and the Chídamulla inlier, it appeared to me that the Anantáram outcrop is really different, its position being higher than that of the others edging the gneiss and that it is represented in the Yenkatapúr promontory by an oddly-placed outcrop of these beds below the Júnjúr-

laguta hill just west of that village; so that there are thus two bands of limestone strata.

In the Mámla region.

The Yenkatapúr beds are continued under the Kámthi sandstones of Pálúncha and appear again in the Mámla hills, at the southern end of which, near Yellambail, the limestone bands also again show in all their altered character, semi-crystalline and saccharoid, but now profusely laminated with silicious matter and some tremolite. The beds are thick and running with a tolerably even strike; but their laminæ are twisted, folded and swollen out in the most curious way, while they roughen the surface of the rock with their outstanding sinuous little ridges.

Here, too, the relations of these Kadapah strata and the gneiss alongside are much obscured by the highly altered and schistose character of the quartzites and other beds; so much so, that I must qualify the lines I have drawn in on the map as to a very great extent doubtful, especially at the Yellambail end. My colleague W. T. Blanford, who first passed over this part of the country, only noted at the time that portions of the higher part of the range are probably of the transition rocks, but I was subsequently obliged to look on most of it as of this series.

Rotangúta and Cherla hills: also with limestones.

Close up to the right bank of the Godávari in this part of the field and opposite Dummagúdem and Párnasála, there is the outlying hill mass of Rotangúta, which is altogether, or nearly so, made up of quartzites (conglomerates and sandstones), all still highly altered and cleaved, but now lying rather easier and giving a fine cliffy face of escarpment to the eastward. On the Cherla side of the river, a further large and isolated faulted-in fragment of the series keeps up the continuation with the great Albáka hill outcrop. The Cherla patch is, for the most part, of quartzites of a very harsh and pebbly character, lying tolerably easy with a rolling dip to the north-westward, except at its northern end where the beds are very silicious-looking, much seamed with silicious infiltrations, cleaved, and rather turned up to the northwards. It is, however, distinguished as having a good patch of grey and blue compact

limestones on its eastern edge on the right bank of the Tál or Tálperu river, the relations of which to the quartzites are not at all clear, though they seem to hade out naturally from under them. This outcrop was largely quarried for the lime used at the anicut and locks of Dummagúdem. Just north of the outlier, there is then a curious wedged-in strip of the same rocks; and byond this is the further faulted straight edge of the Albáka area.

Limestones not seen in the Albáka outcrops.

For the first few miles of this southern extremity of the Albáka range, there is a rather unsteady lie of the beds, still, for the most part, quartzites, amounting to undulation with a general northerly and then north-easterly dip, by which very low beds of the Albáka set are brought up to the surface; but no limestone outcrop is to be found here, like that of Cherla which is practically the feature of that patch connecting the outcrops on the left bank of the river with the Pákál sub-division of the series. It may be said, however, that the broken hilly ground between this Cherla patch and the parallel of Albáka itself consists also of quartzite with a few slaty beds which are very like the Pákál rocks. In any case the strata of this broken hilly ground are regularly succeeded by the more generally quartzite sub-division constituting the proper plateau range of Albáka.

But there are still strata of the Pákál type.

Returning now to the southern end, we may proceed to describe the points worthy of notice in the Pákál area; but before doing so, it is as well to refer to one more abnormal outcrop of rocks at the southern end which may puzzle, as it did me, any future explorer. This is a long narrow and rather curved strip of quartz-schists, about a quarter of a mile wide, which lies just outside the western boundary of the transition quartzites between Rungapur and Balutchmagúdem about twenty-five miles north of Kummummet. The rocks are, for part of this run, exceedingly like ordinary coarse quartzites, but they are striking regularly with the gneiss and dip at various high angles north-eastward,

Strip of doubtful rocks on the western edge of field.

while they are otherwise so strangely placed with the easy lying quartzites of the western boundary a short distance off that they certainly appear to belong preferably to the gneiss series and to be a portion of the schistose sub-division of this, or passage beds into it. At the same time, it may be really a strip of transition quartzites that has been, like many others of similar character along the eastern edge of the transition field in the Nellore district, let in by faulting among the gneisses. If so, it is the only case I know of on the western side of the whole area of the Kadapahs; it is curious also as being close alongside an otherwise very ordinary and simple natural boundary.

Less altered Pákál rocks.

For the rest of the western side of the country the rocks are lying very easy with a varying dip to the eastward, low on the western edge, then undulating and becoming rather higher further inland, and even having sharp folds and sometimes high and nearly vertical dips in places. The whole series as exposed in the Pákál hills is also made up of what may be called sub-groups of quartzite limestones and slates, which in certain parts of the field overlap each other; the usually bottom quartzites, for example, being sometimes extensively overlapped by the succeeding band of limestones. An evident sub-division of the series is as follows in descending order:—

A rather slaty band with several thick seams of quartzitic sandstones	3,600 feet.
Grey and faun-colored silicious limestones	300 „
Clay-slates with quartzites	500 „
Silicious limestones in one or two bands	150 „
Quartzites with a few slates	700 „

Approximate thickness.

It is utterly impossible to give any fair idea of the thickness o this series, for there is a good deal of folding, some reduplication, and, no doubt, some local faulting, by which repetitions of the same strata are brought up to the surface; but it must be at least 5,000 or 6,000 feet. The greatest width of outcrop is about due east of Hannimkonda or on a line running through

the great Pákál tank; and, to all appearance, there might be here a regular succession of the different sub-groups in a direct line of more than twenty miles, which would, at what appears a fair average dip of 8° give a serial thickness of 14,500 feet. There is, however, no use in relying on an approximation of this kind, and it will be best just to note thicknesses of portions of the series which can be verified at certain localities.

Going east from the Pákál tank the coarse largely crystallised grey gneiss is overlaid by massive sandstones and conglomerates, which form a belt of about a mile or so in width, and of which the thickness may be 800 feet. At the north end of the embankment of this reservoir, these quartzites are succeeded by sandy flags with earthy shales, and then by slaty shales or coarse clay-slates, a knoll of the latter at the end of the *bund* or dam having been levelled down as a flat terrace for some old building site. The slates of the knoll are nearly flat, but the dip increases as the eastern slopes are traversed. These slates are next succeeded by a good thickness of quartzites dipping 20° to 30° east-north-east or so, which go to form much of the high ridge running into the tank from the south side; and these in their turn are followed by a great width of clay-slates with a few quartzite bands, forming the somewhat more level country of Pogulapully on the western shores, the dip being again low, though now to south-west for a short time. At Rúdraram[1] there is a further band of coarse quartzites which in their dip of 30° to 40° westward, might be a hading-up of the bottom quartzites by an undulation, only that between this village and the next highest ridge there is a broad outcrop of brown-weathering grey limestones, which is not represented to the westward. These silicious limestones are associated with slates, and, at their low dip of 5° to 10° east-south-east, form about half a mile of the width of a broad terrace, the rest of which is made up of clay-slates.

Traverse across the widest part of field.

This Rúdráram and Músmi terrace is succeeded by a high ridgy

[1] Four miles east-north-east of Pogulapully.

mass, the backbone in fact of the Pákál range, which must reach elevations of 1,800 or 2,000 feet above the sea. The first ridge is of quartzites, and these are succeeded by earthy slates with frequent bands of thin beds of sand-stone. The cleavage of the slates is north-north-west, with a high dip to the eastward. Next comes the high ridge just before descending to the Kámawaram terrace, and this is mainly made up of thick and strong beds of quartzites which have rather a more undulating lie than the strata of the western part of the hills. The rocks of the Kámawaram terrace are mainly slaty beds, rather earthy and sandy with thin bands of quartzites; and then come broad bands of generally red-purple flags and earthy slates with seams of blue and grey beds, among which are frequent narrow bands of quartzite, right up to the Kámthi boundary. All these have a very varied lie, sometimes undulating, or even horizontal, and at others dipping eastward then westward at various angles, or again being quite vertical.

The limestone outcrops, upper and basal.

To all appearance there is only one outcrop of limestones, though there is no certainty in such a wild and jungle-covered country as this is that other outcrops may not have escaped my notice, and it is, as far as I could make out, an extension northward of the Anantáram band in the Singareni field. So far, the lower outcrops of Singareni are not represented on this side, except at intervals, as at Utla, inside of the peculiar strip of quartz schists already described as fringing the western boundary, and then only very poorly. The double character of the lowest southern outcrop seems to be caused merely by the intercalation of a thin seam of the sandstones, for here at Utla there is certainly only one band. But on going still further north, two very decided outcrops begin to show and are very well displayed in the low hilly tracts between the large Kotapet tank and the Manér river, which certainly give the idea of two separate bands. These are continued northwards to the Manér, and are very well displayed in the wide belt of now flattened-out beds between Velchal and the Encharáni hill. It is in this last field, however, that

The lower band sometimes double.

the whole evidence combines to show that there is really only one good band about 150 feet thick of such beds, and that the apparent double character is mainly produced by local faulting about Kotapet, Bagerlipet, and Zukkáram, and by denudation on an anticlinal fold further northwards.

The uppermost band of calcareous rocks in the Pákál hilly tract, on the Pogulapulli and Músmi terrace, is traceable northwards for a few miles, and then it becomes covered up by the superficial deposits of the Mulug valley, in which the large tanks of Paliampet and Kotapet are situated.

Character of the slaty beds.

Throughout the most of this Pákál area, the slaty beds, or clay-slates, are always poorly cleaved, and they are rather coarse slaty flags than clay slates, while very often they are earthy and sandy; but, as they are followed out northward, they become rather more compact and fine-grained, particularly in the lower portion of the series, towards the Manér river, though here they are thin and badly exposed owing to the very flat lie of the beds and the greater prominence of the hard splintery limestones. However, on the north side of this river there is a better display of the lower set of quartzites slaty bands and limestones in the now more broken hilly ground, and here the limestones are less prominent, while the shales are decidedly finer in texture becoming green and purple in color and much banded with thin calcareous seams. Indeed, the latter resemble very much the fine slaty shales of the Cheyair group of the typical formation on the western edges of the Kadapah district.

Separate northern extension of western outcrops.

A few miles north of the Manér, the outcrop of the Pákál rocks ceases abruptly, being brought up against the Gondwána sandstones by a line of fault; and no more is seen of them for several miles north of the Godávari or until about the parallel of Tándúr, where they again form the wild hilly and jungle region beyond the Timapúram and Waripet ridges. They are then covered up by the Deccan traps of the Jángaom valley, but they re-appear in the low hilly masses between this valley and

the Wardha country; and, with them are the same purple shales and limestones which we left on the Manér river, only these are now lying directly on the gneiss.

The Wardha outcrops supposed hitherto to be Vindhyan.

This latter area has been visited, I believe, by Mr. W. T. Blanford, and certainly by Messrs. Hughes and Fedden; I only saw it myself in a flying march made from the Jángaom valley to Warora at the end of a working season. At any rate, the rocks have hitherto been referred by us all to the Vindhyan series; and some of them have been considered as representing the group of em shales, or Pem beds, originally described by Blanford. Concerning them Hughes writes:[1] "They consist of sandstones and semi-quartzites, shales and limestones, and occur in this order, the shales being also intercalated with the limestones.

Hughes' account of them.

"They came but slightly under my observation, and I am not able to speak authoritatively as to the exact geological horizon they ought to occupy; but they are supposed to represent the lower division of the series which has been traced through Raipúr and the upper courses of the Mahánadi into close proximity with them.

Doubts about the quartzites.

"It is not quite clear whether all the sandstones of this area which are included under the head of Vindhyans ought to be classed with the limestones and shales as constituting a connected series, or whether they ought not to be elevated to the dignity of a separate and, perhaps, younger formation; and until they are more closely examined, the doubt cannot be set at rest."

I will just remark now, *en passant*, with regard to this doubt of Hughes as to the occurrence of only one set of sandstones, that I have got a series of quartzites or sandstones, overlying thin slates or shales and limestones like those of the Manér and the northern side of the Jángaom valley on the Wardha-Pránhita valley, which I consider to be lower Vindhyans.

[1] Wardha Valley Coal-field, *op. cit.*, p. 11.

To continue Mr. Hughes' observations—"*Shale group.*—This group is made of earthy slates, and occasional beds of flaggy limestones. They are very fine-grained, with a somewhat nodular structure, and much jointed. When they weather, they split up, like the Tálchir shales, into small, thin, discoidal fragments, and an isolated outcrop of them might readily be mistaken for that series. Their usual color is some shade of red."

Character of the slates.

Concerning the limestones he writes—"They are usually thin bedded, and of a pale or dark grey, or buff color, seldom red, like their associates the shales."

The limestones.

Mr. Medlicott, in his treatment of the Vindhyan series, in the Manual of the Geology of India (p. 74), has made the following remarks, which also fit in to this discussion:—"*Máhánadi and Godávari areas.*—Between the Karnul and Bhima basins on the south, and the main Vindhyan basin on the north, of which somewhat detailed descriptions have been published, there are numerous areas, some of them very extensive, in the Máhánadi and Godávari river-basins, occupied by rocks belonging either to the lower Vindhyan or to the upper transition series. These rocks consist of limestones and shales, mostly in low ground, and of quartzitic sandstones commonly forming ridges and plateaus. They have only received cursory notice in connexion with the adjoining formations, or during rapid preliminary surveys of large areas. Mr. Blanford first noticed them in the country on the Pemganga, south-west of Chánda, and conjectured their Vindhyan affinities; he considered the sandstone to be the lower member of the series. Coming from the south, Mr. King recognised the quartzites of the Pákál country north of Kamamet as Kadapahs (they are colored so on the map accompanying the Manual), and certainly one would *primâ facie* conjecture them to correspond with the bottom sandstones of the Palnád on the Krishna. An observer from the north, familiar with the lower Vindhyans of the Son valley, considered the limestones and shales of the plains of Chhattisgarh to represent

Mr. Medlicott's remarks on the same rocks.

that formation. This opinion is now quite general as regards the principal shales and limestones of these several areas; but there is still considerable doubt as to the position of the sandstone or quartzite."

My latest explorations show that the shales are Kadapahs.

Now, with regard to these remarks of Mr. Medlicott, it just happens that the purple shales and limestones are those on which we have all split, or rather from which we have all drawn our several conclusions up to this time regarding the age of the series; and necessarily so, because they are more distinctive than the quartzites.[1] As a matter of fact, shales of more or less red and red purple colors, associated with limestones do occur in both the Kadapahs and Karnuls, which are in certain areas scarcely to be distinguished from each other. When I saw the shales, etc., in this region I had not seen the beds on the Manér, and I was then inclined to look on Blanford's sugegsted Vindhyan age of them as the right one, but now I cannot but look on them as a northerly extension of the purple states on the Manér and thus as belonging to the Kadapah series.

Similar rocks in the Bastar country.

I can also, as it happens, give a rather decided opinion as to the quartzites, limestones and shales of the eastern or Bastar area, which is only an extension of the Mahánadi field; having purposely made a march from the eastern edge of the Kadapahs on the Pránhita-Godávari field to look at the rocks which had been traced so far westward by my colleague Mr. Ball,[2] and which are considered by him to be of Vindhyan age. He writes thus:—"In Bastar the rocks seen consisted chiefly of red flaggy nearly horizontal beds of sandy clays; these, at Karinji, are seen overlying quartzite sandstones of, apparently, no great thickness. These beds are in places calcareous, and occasionally impure red limestones occur. I was unable to visit the Chiterkot falls on the Indravati, but specimens brought thence included fragments of vitreous quartzite, and a black shale like that found at the base of the Karial quartzites."

[1] When the Manual was written, Mr. King had not reported on the Wardha ground, to which his present remarks would apply.

[2] On the geology of the Mahánadi basin and its vicinity.—Records., Geol. Surv. of India, Vol. X p. 180 (1877).

Luckily, I was able to get to these Chitarkot falls, and there I found the quartzites and black shales above referred to. These quartzites extend several miles further to the westward, until they are seen to overlie the gneiss, mainly horizontally. They are themselves overlaid by the red purple limestone and shale series in regular order, and these shales and limestones pass over the quartzites on to the gneiss.

As far as lithological resemblance goes, the purple shales and limestones of the Chitarkot terrace are exactly the same as the shales and limestones of the Warda-Pránhita valley. The shale and limestone and is overlaid by a yet higher zone of quartzites, forming the highest upland plateau of Bastar south of Chitarkot; but I did not see enough of this to say whether it belongs to the Kadapahs, or is a representative of the Sullavai group next to be described.

My own cursory examination of the Sirpur rocks.

Returning however, to the north side of the Jángaom valley, what I saw of it myself was sufficient to show that the rocks are quartzites, limestones and a thick set of fine red and purple shales, with seams of pale-green, harder and sometimes jaspideous shale, this being also their succession in descending order. The shales rest on the gneiss directly, on the Wardha side of the country.

The position of the two quartzites.

I think also that there are two different sets of quartzites in this region: that the quartzites overlying the shales and limestones may really be representatives of the newer set of quartzites and sandstones which are described here under the name of the Sullavai series; while the sandstones described by Blanford as underlying the shales must here be overlapped by the shales, and may be represented by a small outcrop of quartzites in the hills north of Aksapur.

One, a representative of the Sullavai beds.

The settlement of the relations of these quartzites and purple shales was eventually much facilitated by my recognition of the next series of rocks (Sullavais) as a distinct and unconformable series on the Kadapahs of Pákál, and by the presence of the same series on the eastern side of the field,

where it overlies further outcrops of the shale and limestone rocks of the Sirpur country.

My own more particular examination of the series as it is represented in this part of the country, namely, by quartzites and a red-purple slaty shale bands with limestones, was on the eastern side of the field along the Wardha-Pránhita valley and so down by the Indrávati and left bank of the Godávari; and here certainly, the limestones and shales—oftener shales—are the lowest beds of the series and rest directly on the gneiss.

The rocks on the Wardha-Pranhita side of the country.

The first trace of these occurs along the left bank of the Dábha tributary of the Wardha at Karinja; a faulted strip of hard splintery grey limestone beds, some of which are very conglomeratic with pebbles of red brown and yellow jasper and chert, limestone, and quartzite. These are remarkably like some of the shore beds in the Kadapah field about Karnul. The beds are rolling about, but have a general low western dip; or they are at times much crushed and then seamed with red and grey jasper and chert. The next outcrop is some miles to the south below the Ambaguta hill station, where they pass round the western base of the hill, apparently underlying the thick set of beds composing it, which, however, belong to the Sullavai series. The beds are always the red-purple shales associated with limestones; in fact, fair Pem beds: further down the Pránhita, about Mutlagúdem, they become associated with other slates and quartzites, after which there is, in the Sironcha country, a more general display of the Kadapah facies. These Pem rocks are again well represented at Muthpalli on the northern edge of the Sironcha hills, and again on the Indrávati near Bhopalpatnam and at its junction with the Godávari, where this lower, or, what I prefer to call the Pákál division of the series, appears to roll down under the quartzites of the Albáka range.

The crushed up character of the Sironcha strata, ceases in the Albáka hills.

As soon as the Indrávati is crossed at its junction with the Godávari, the very folded and crushed-up condition of the Kadapahs in the Sironcha country entirely disappears; and henceforth, for fully 96 miles to

the south-east, in fact down to Albáka, the great range of quartzites then flanking the left bank of the Godávari exhibits the easiest stratigraphy possible. The beds are lying remarkably flat or in a great flat wave, except along the eastern edge, where they roll about rather and then dip down to the north-eastward, eventually abutting quite abruptly against the gneiss. To a certain extent the strata in the Sironcha hills become, as they strike at the Indrávati and Godáveri, less squeezed up together and open out, as it were, into a series of parallel folds which are exhibited best in the Enchapali hills and the immediate bed of the Godávari, and thus they would appear to roll down under the Albáka beds, but I do not think that there is really such a simple roll under. The break from such contorted strata as occur on the right bank of the Indrávati, to the easier lying beds on the Depali side is too sudden for such a simple roll; therefore, the probability is that a break of some kind does occur here.

The strata of the Albáka range.

The northern end of the range overlooks the Indrávati-Godávari junction by a lofty and very steep escarpment rising almost sheer up from the low country of Depali to a height of 1,625 feet; and along this face the stratification of the low eastward-dipping beds is very finely displayed in bands of darker or lighter colors and more or less breadth according to the thickness of the quartzites and flaggy seams. There can be no mistake here as to the thickness of so much of the series as is represented in this range of hills; so, for the northern end, there are at least 1,300 feet of strata exposed above the low country level, of quartzite sandstones and occasional conglomerates and pebble beds with bands of thinner beds and flags, and some slates. At the southern end, and still on the western scarped edge of the range, and behind Albáka, a height of 1,619 feet is attained; while away eastward towards the back of the range, the highest escarpment runs up to 3,174 feet. Albáka is about 350 feet above the sea and is on quartzite and slate beds of the lower part of the series, and thus the lofty escarpment behind shows at least 1,260 feet of the more generally sandstone division. Again, on the outlying

plateau mass, with scarped sides all round, of Kotapali, 8 miles east of Albáka, there must be 1,500 feet of these upper beds; so that we may safely look on this sub division as fully 1,400 feet thick, from end to end of the range.

The whole series consisting of two divisions.

We thus have, for the whole display of the Kadapah series in this region, a succession which appears to consist of two tolerably well marked members: namely, a more or less slaty division with very many strong bands of altered arenaceous beds, in which are at least two bands of limestone, which is more particularly developed on the western or Pákál side of the country; and a higher division which is more generally arenaceous in its constitution, on the western side of the field. The extreme total thickness of the two may also be reckoned thus:—

	Feet.
Albáka sub-division	2,500
Pákál „	5,000
	7,500

I think the Albáka rocks do run thicker than this in reality, and I would make them thicker; only, there is a doubt in my mind as to whether the strata of the higher scarps may not be of the next higher series, their lie being not quite with the great scarp beds.

CHAPTER VI.—LOWER VINDHYANS.

A set of rocks unconformably overlying the Kadapahs.

The Sullavai Sandstones.—The Transition rocks of Pákál, and the northern portion of the same series on the eastern side of the country, as at Dewalmári on the Pránhita and in the neighbourhood of Bhopalpatnam on the Indrávati, are overlaid by a series of quartzites and sandstones presenting peculiarities of lithological constitution which make it difficult to correlate them with the Vindhyan rocks of the Madras Presidency, but which must, I think, for the present at any rate, be considered as belonging to this series.

In the previous notices of the rocks of the Pránhita-Godávari basin, published by Hughes and myself in the Records of the Survey, these rocks are referred to as the Kápra sandstones, our attention having been attracted by them at Kápra; but they are better seen at the larger and more known village of Sullavai on the road from Hannimkonda to Mangapet, which is besides of some importance as the residence of a Mahomedan chief, while it is also in this neighbourhood that their unconformity on the Kadapahs is best seen.

At Sullavai.

In the Pennér and Kistna field of the upper Transitions, the next overlying formation is the Karnul series, and it might naturally be thought that this sub-metamorphosed set of rocks of Sullavai is representative of that series. There is, however, very little similarity between the two, except that they are both largely made up of quartzites, and that there is a certain remarkable and strong physical resemblance between a group of peculiarly weathering beds in each. Then, there is no similarity in the grouping of the two series; and there are no limestones known in the Sullavais.

Compared with the Karnul series.

In so far as it is in great part an altered series, being made up partly of decided quartzites and some slaty beds, it is more closely connected with the Kadapah series than with the later formations which are quite unaltered and, comparatively speaking, much younger. At the same time, though this is only developed to a small extent in the north-eastern outliers of the series, the faulting which affected both the gneiss and the Kadapah rocks, and which occurred prior to the deposition of the later rocks appear to have affected these rocks.

More related to the Transitions than to the later formations.

The series consists of, lowest, a varying thickness of massive quartzite sandstones and conglomerates with a few slaty beds, very like ordinary Kadapah or Karnul rocks. These are succeeded by a set of generally salmon-red or chocolate-colored sandstones, blotched and dashed with white and buff colors of rather finer texture and much less indurated than the

Lithology.

quartzites, looking indeed often like ordinary unaltered sandstones. These are remarkable in their dark-colored weathering of a nearly black-purple or dark chocolate color; and in their generally rather smooth and rounded outcrops, though the surfaces of these are still very harsh. Next comes a strong series of thick and thin bedded quartzites, or more indurated sandstones, very pebbly and gravelly, which in their peculiar and picturesque form of weathering bear some resemblance to the 'pinnacled' quartzites of the Páneum group of the Karnul formation in its typical area.[1]

The grouping thus made out may be distinguished by typical localities, thus :—

Sullavai Series.	*Kápra sandstones*	...	700 Feet.
	Venkatpur sandstones. (Salmon-red beds)	...	300 „
	Enchardni quartzites	...	600 „

Unconformable on the Kadapahs.

At Sullavai, the lower groups form a series of low hills on the south side of the high road, whose long sloping surfaces rise gently up to the northward with the dip, giving several broken and jagged scarps in that direction; and thence they may be traced up the bed of the Buswapur stream nearly to the large tank. About a mile from this, the lowest beds can be seen overlying the nearly vertical slates and quartzites of the Kadapahs in the most perfect condition of unconformity. The lowest bed in this section is a very heavy conglomerate or shingle bank which thins out along the outcrop undulating over the upturned edges of slaty shales and thin bed of harder shale and quartzite, and it gradually changes upwards into more uniform beds of sandstone, the dip of all being easy, about 5° to the northward.

Westward and northward of Sullavai, in the second large stream, crossed by the road to Venkatpur, the unconformity is again quite plain, where at a short distance back, up the nala, these rocks are lying on denuded shoulders of quartzite outcrops, on faces of bedding and over the upturned edges of quartzite and slaty shales; the lie of the Kadapahs being here rather crushed-up and folded.

These sections in the neighbourhood of Sullavai are most opportune,

[1] See Mem. Geol. Surv. of India, Vol. VIII, Part 1, p. 52.

for, though the general unconformity and overlap of the series on the Kadapahs is quite evident over the whole field, there is, nevertheless, a remarkable apparent parallelism of strike between the two formations northwards from Sullavai right up to the Manér river. It is, however, in this direction that overlap is very evident, where, as the Godavári is approached, lower and lower strata of the Kadapahs are gradually covered up by the Sullavai beds; and that, finally, between the Manér and the Godávari, as in the Mantani doab, the Ramgir plateau hill is formed entirely of them, as they lie directly on the gneiss. North of the Godávari, they crop out again from under the Tálchirs and form the Timapuram ridges, and thence carry on to the northern limits of the field; the Kadapahs also in their turn, but not until after an interval of some miles of contact of the Sullavais with the gneiss, crop out and again form the intervening rocks between them and the crystallines.

Overlap in the western outcrops.

At Sullavai and in its neighbourhood, the strata are lying easy, and they show very little traces of cleavage; but, as they are followed northwards to Venkatpur, even though they are still lying at low angles, to the eastward, the strike having now trended round more north and south, they are cleaved in north-north-west to south-south-east planes to such an extent that the bedding is rather indistinct, the thick intercleaved bands at first looking more like high dipping beds. Here, there is a broad bare (there being little soil for jungle growth) belt of smooth-worn but rounded outcrops of dark purple and black weathered cleaved[1] sandstones edged on its eastern side by the narrow belt of Tálchirs.

Cleaved beds of Venkatpur.

[1] Mr. Medlicott suggests that these may be jointed rather than cleaved sandstones; they certainly did not strike me in this way, the two systems of jointing (generally east and west, north-north-east and south-south-west) being very plain. Here cleavage planes, as I prefer to call them, are certainly developed at much wider intervals than are usual with slates, but there is at the same time a visible lamination between them, just as in ordinary slates, along which I have little doubt that the rock might be split up with a slate chisel, though not to suchan in finitesimal extent as with slates. I only know of one case, in the west of Ireland, on the south side of Galway Bay, in carboniferous limestones, where the joint planes are so close together as is usual with cleavage planes; but the rock there cannot be split up in any thinner sheets than those developed by jointing.

Kotapet outcrops.

Northwards from Venkatpur, the country is much covered up for many miles by superficial deposits until about Kotapet, where rounded humpy masses of the unmistakeable dark-weathering sandstones again appear, proving the continuity and extent of the series. Thence there is a broad spread of the same rocks up into the Kápra area; while the underlying quartzite member of the series which has all this time kept along in the Paliampet ridges runs out from under them to form the great headland of Encharáni.

The display near Kápra.

The Kápra country is remarkable for a group of strange-looking isolated and nearly vertical-sided tabular masses of sandstone strata which stand out conspicuously in the generally flat country over the far-stretching jungle. They reminded me slightly of the Paneum buttressed and pinnacled masses in the Karnul district; they are, however, larger, and they do not, as there, stand out so clearly from a denuded plain of the same rocks, though this may be owing to there not being such an extensive exposure of them. At best it is but a faint physical resemblance.

Succession.

The Kápra strata are nearly horizontal, reddish buff and grey sandstones, approaching very closely the character of quartzites; thin bedded in the upper portion, and thicker bedded and conglomeratic at the base of the tabular masses. A lower portion of them out in the low country is exceedingly rough with pebbles and seams of sharp gravel. They rest on softer salmon-red and dark-weathering laminated fine sandstones, similar in every respect to those of Venkatpur; and below these are again the very heavy and thick-bedded quartzites which run up westward to form the great Encharáni headland. The succession of the series is here—

Kápra beds	...	...	100 feet, about.
Venkatpur, or salmon-red beds	...	...	200 „ „
Encharáni hill beds	...	...	900 „ „

Gravel and pebbly beds of the Kápra group.

To the north-west of Kápra, on the right bank of the Manér and west of Tárcherla, there is a great display of the coarse gravel and pebble beds of the lower portion

of the Kápra sub-division, and the weathered-out detritus is strewn over and around the low ledges in wonderful profusion. These pebbles are of quartz quartzite and various colored cherts, both rounded and sub-angular; and they stick out over the surfaces of the beds in a most prominent manner. Indeed, this rough pebbly and gravelly character of the beds is remarkable not only here but in other parts of the field, and it is more characteristic of this group of the series than any other set of quartzite or sandstone conglomerates in this or the Kadapah formation.

Clays, &c., of the Venkatpur group.

In the same region, but southward on the road to Kotapet, frequent outcrops of bright red and vermilion-colored clayey sandstones and clays characterise the Venkatpur sub-division, or the salmon-red group, and may indeed be mistaken at first for some of the red clays of the upper Gondwána series. Other clays of dark purple color also occur far to the south in the Venkatpur and Sullavai country, which were for a long time troublesome, in that the Tálchir boulder bed is sometimes of the same color.

Outcrops north of the Godávari.

The further outcrops of this series in the Timapuram ridges beyond the Godávari are unmistakeable, the typical dark-purple-weathering rocks occurring in great force as the grandly picturesque mass of hills just north of the village. The strata here are dipping at rather a higher angle than usual, and thus there is a more broken combination of ledges scarps and tilted-up tabular and pillared masses. The triple grouping of the series is fairly exhibited here.

Beyond Timapuram, the country is much broken up into lofty hills and ridges, covered with jungle and very difficult to be traversed owing to the paucity of roads and there being no villages; we had thus not much opportunity of going carefully over it, especially in the short time at our disposal, but we saw enough to show that both this and the Kadapah series do occur in this tract of country. The boundaries are only put in provisionally.

Rocks of the inliers.

The two inliers of Kistnapet near Chinúr and Damarakúnta near Mádapur towards the Pránhita-Godávari junction, consist of eastward-dipping strata of the typical salmon-colored and blotchy sandstones from under which the more indurated beds of the Encharáni sub-division rise up to the northward in the hill station at 987 feet. About Kistnapet there are very extensive outcrops of the finer grained and laminated salmon-red and purple variegated beds which are largely quarried for a very excellent building stone, and they show up here and there nearly down to the bank of the river.

In the Wardha valley.

We have not been able to map out any outcrops of the Sullavais in the north-western corner of the field beyond the Jángaom valley, because there has not been an opportunity afforded for our re-visiting the country since I distinguished these rocks as a series; but, from the little I saw of the country, I think it very likely that they do occur there. Mr. Fedden tells me that he all along felt that there might be two series of quartzites, or quartzites and sandstones, one of which is associated with the purple slaty shales and limestones, as an overlying series, while the other seemed to be as clearly on a lower horizon. Mr. Hughes also had considerable doubts as to whether the slates and quartzites of these hills all belonged to one series.

The eastern outcrops.

At any rate, as on other parts of the field, the purple slates and quartzites of the pass leading over these hills into the Wardha valley are the bottom rocks, and rest on the gneiss; and similar rocks are again met with in the Wardha-Pránhita valley, where they are associated with two extensive outcrops of the Sullavais in the Ambagúta hill and the Dewalmári range further south.

Ambagúta hill.

Ambagúta hill (1,471 feet) is a huge mass of this series faulted in among the gneisses and entirely isolated from any main area; and it is flanked on its western side by a narrow strip of silicious limestone and red-purple shales of the Kadapah series which are squeezed up, infiltrated with quartz, and lie either vertically or at a high angle to the eastward. I could find no junction;

but a mile or so eastward, the basset edges of Sullavai quartzite sandstones, and pebble beds, crop out as the steep western slopes and escarpments of the hill mass.

In the Dewalmári range.

The Transition slates and limestones carry on, however, to the south-east across the river to the Dewalmári country, and run close up to the northern edge of the larger hill range lying to the south of the village. Here, again, all junction is concealed by jungle and talus débris, but there is such folding and high dip of the quartzite of the Dewalmári hill on this side, that I hardly think there is a natural boundary here, or that the Kadapahs run under them without a break. The junction of the two series, in the same range, on the right bank of the river, is clearer, and there is no doubt that for much of its length the Sullavais of the Dewalmári range are lying unconformably on the Kadapah slates and limestones.

Three groups well exposed.

The Dewalmári hills are a grand, partially plateau and scarped sided mass of the Sullavai series, the strata of which are lying in a shallow basonal way, though with a general dip northward and eastward; and its highest portions must be at an elevation of about 2,000 feet above the sea. On the western side, the Pránhita has cut very deeply into the series; but still, the range and its strata are continued on the right bank of the river at lower and lower elevations until in the Baiaram and Mutlagudem valley the underlying Kadapah rocks come to the surface. The southern and eastern edges of the range are grandly scarped with lofty lines of sandstone cliffs below which are steep undercliffs of gneiss, but the eastern side lowers to the north, its scarped lines running down with the dip, until there is no undercliff of gneiss, the crystalline rocks only occurring in the proper low country.

At first sight, one would take this scarped range to be a mass of unmistakeable Kadapah strata, it is in many respects so like, in its scenic features, and even in its rocks, other hilly masses of this formation in its typical district; but an examination of its constituent rocks soon shows that they are of the Sullavai series.

The grand southern scarped edges are of coarse, massive, and thick-bedded quartzites of the Encharáni sub-division, which dip down from the edges of the range under good dark-weathering red purple and salmon-colored sandstones of the Venkatpur type. These last form the greater part of the floor of the wide valley inside the eastern half of the range, and then, over these, and forming nearly all the higher western half of the range, is a great thickness of the more pebbly and gravelly banded indurated quartzites of the Kápra sub-group, rising in magnificent cliffy buttressed and pillared masses, one of which stands out as a hill-station having a height of over 2,000 feet, the upper 200 of which is almost inaccessible. The three sub-divisions are as clear as the noon-day in all their characteristic features of constitution, mode of weathering, and color. The Kápra beds, exposed in the steep cliff faces and tabular masses which are all lined with the strong partings, at broad intervals, of the thick and massive strata, or banded with narrow ribboning, where the seams of flaggy and pebbly beds come in with greater frequency, and which rise up for fully 700 feet in thickness, over the longer and curiously contoured slopes of the gradually darkening series of the salmon-colored beds below. Lower down, these last are spread out in great flatly-worn rocky surfaces, with little vegetation, which are cut into in the most strange way by the streams which flow in long and deep vertical-sided ravines as long as they are in these fine-grained soft beds. This cut-up condition of the flat part of the valley is most striking when looked down upon from the lofty hill-station; the main stream running along in the east-south-east to west-north-west joint planes, while its side-feeders are running in the more north-north-east and south-south-west lines. In and out of these ravines run contoured terraces of bedding, in the most regular manner; while all the time the ravines are cut down so vertically and deeply that one can only see traces of the streams themselves, or of the vegetation which is hidden away down among the smaller cliffs and buttressed pillars. I suppose, for such a small stretch of flat valley, there is about the greatest difficulty of crossing it on foot in any direct line, the only convenient

path being round its western edge, or along the contoured terraces at the head of the deeper drainage.

Their thickness.

There must be, at the least, a thickness of about 1,500 feet of the series displayed in this range, the greater part being made up of the Kápra beds; of which there is only a remnant, as it were, left on the Hannimkonda side of the country. The Encharáni beds, as exhibited in the southern scarp, may be 600 feet; then there must be about 300 feet of the Venkatpur beds exposed in the valley, and over them are fully 700 feet, if not more, of the Kápra beds.

Arjanali outcrop.

A further, but now very small, patch of the series occurs some 50 miles to the south-east, in the Bhopálpatnam country, as a rather picturesquely scarped mass just south of the village of Arjanali: and it consists of the lower beds of the series, of which there are about 200 feet, resting unconformably on red-purple shales, and limestones of the Kadapah series.

Possible outcrop on the Albáka hills.

The occurrence of this small patch down here has always raised a doubt in my mind as to whether much of the eastward slopes, or even the higher portion of them, of the Albáka range may not also be of this Sullavai series, especially the strata forming the Doli capping and escarpment, which on certain views looked to have a somewhat unconformable lie on the rest of the range. As far as I could see at the time, and under the circumstances of a very rapid examination of the hills, the whole mass certainly appeared to be of the Kadapah series; but it is just possible that I may have carried this too far, and that the Doli beds may be of the newer series.

CHAPTER VII.—THE LOWER GONDWANAS.

Grouping.

The several series of rocks already described are at certain places succeeded and overlapped, in strong unconformity, by different groups of the lower members of the great plant-bearing series which of late years has received the name of the Gondwána System. These are the Tálchir, Barákar, and Kámthi groups.

The Tálchirs are poorly developed, and the Barákars—the only proper coal measures of the Central Provinces and Hyderabad—have only a very small thickness; while their outcrops are rare and in a few cases quite detached from the main field. The Kámthis, on the other hand, are of very great extent and considerable thickness. All three groups are well separated by overlap, though they are never entirely disassociated for any distance. Over a large tract between the upper or Mánér bend of the Godávrai and Sullavai, the Barákars have no very clearly recognisable outcrop, though the Tálchirs and Kámthis are in great force. Only in one locality, near Beddadanol, in the Godávari district, is there an instance of coal-bearing strata cropping out from under the Kámthis unassociated with Tálchirs.

Kámthi group enormously developed.

The whole Gondwána system, as here represented by the various groups but always pre-eminently so by the Kámthis, extends in an unbroken stretch from the Wardha valley to within a few miles of the deltaic deposits of the eastern coast near Ellore. These were in the first instance so traced from the Central Provinces by Mr. W. T. Blanford; subsequently, I worked them out with more detail up to Sironcha where I joined boundaries with Mr. T. H. Hughes, who was, in like manner, carrying them southwards from his Wardha valley coalfield.[1] The full width of the southern part of the tract is occupied by lower Gondwánas, the Tálchir and Barákar groups cropping up at intervals on both sides of the field; but about half-way up the valley the Kámthis become gradually overlaid by higher and higher groups of rocks whose plant remains make them of the upper division, and which are at their strongest on the Pránhita, and so continue widening out until they occupy nearly the whole width of the northern half of the valley. In the extreme south, the Kámthis are again covered up by plant beds and marine deposits of Rájmahál and upper jurassic age, which are, however, quite unconformable on them.[2]

Extent of the Gondwána formation.

[1] Mem., Geol. Surv. of India, Vol. XIII, part 1.

[2] Mem., Geol. Surv. of India, Vol. XVI, part 3.

General thickness of lower divisions.

The lower Gondwánas have a great ascertainable thickness, though this is small as compared with the enormous serial thicknesses implied by some of the river sections. As exhibited in the Gundikámáram hill range between the Mánér and the Sullavai valley, a thickness of over 2,000 feet is manifest at once; while the river sections often give an apparent succession of from 6,000 to 8,000 feet, which is, I think, gained in great part by possible step faults. We may safely reckon, however, on the Kámthi group alone being fully 4,500 feet at the thickest. The Tálchirs and Barákars are again so thin, comparatively speaking, as not to be of much consequence in the general thickness of the whole series: the first may have a thickness of 200 feet at the very highest, and the latter seldom run beyond 300 feet.

The Kámthis alone fossiliferous.

In all the vast area of lower Gondwánas, the finds of fossils have been very poor and then only in the Kámthi group; indeed, of anything, this was the set of beds more particularly searched for fossils, their relations not being so evident all over the field, while the other groups, as being lithologically very clear, were not searched so closely nor are they so well cut into as the upper member.

A fair coal region.

Fairly good indications of coal were found in the southern part of the field as well as in some small but widely separated areas on the lower Godávari, but all these places are badly situated for the getting out and exportation of the fuel.

Boulder bed.

Tálchir group.—The Tálchirs are represented by the well-known boulder bed and a few thick-bedded fine greenish-colored sandstones usually associated with it; but this boulder bed presents some variations in the constitution and appearance of its matrix which deserve closer description.

In the Dummagúdem outcrops.

In the southern part of the field, as in the neighbourhood of Bhadráchalam and Dummagúdem and again in the small coal-field of Singareni 40 miles away to the

west-south-west, the rock is the usual dull olive-green or yellowish-green hardened fine silt or sandy silt, rather micaceous, more or less filled with pebbles and smoothed boulders of all sizes, from that of a hazelnut up to huge blocks, of greenish gneiss, quartzite, indurated slaty rock, and limestone, all of which are lying in the matrix without any order as to deposition by their weight or other obvious cause. There is no regular bedding in the rock, only a sort of rude arrangement, at times, in lenticular masses, which might be considered as a kind of pseudo-stratification, and at Dummagúdem, on the opposite bank of the river, there is sometimes a slight appearance of bedding when the boulders are in less profusion: the proper boulder bed gradually changes upwards into fine soft micaceous sandstones, some of which are sufficiently massive and bedded to have been extensively quarried for the larger stones in the great locks of the navigation works here.

Volcanic look at Kámawaram.

In other parts of the field, and especially in the outlying small coal-field of Kámawaram in the Pákál hills, the boulder bed puts on a remarkable resemblance to volcanic deposits. The ordinary green silts and muddy sandstones are to be seen at Kámawaram, but much of the outcrop is made up of nearly black dark purple brown and blackish-green ashy-looking rock, often minutely vesicular and cindery, at times also concretionary, and seamed with dyke-like bands of more compact and stony material. These are, however, associated with pebble beds and conglomerates having the same matrix; and, on a very close examination, they are also found to contain large pebbles and to be more largely charged with very small pebbles and granules which, on falling out or becoming decomposed, give the vesicular appearance to the rock. I was not successful in finding any good specimens of rubbed boulders, though many had an appearance, when dug out, of rubbing or striation on the protected side. Some large boulders of granite in the outcrop on the Godávari above the Pránhita junction had polished surfaces, but these might be due to the river action, and the generality of the boulders in the outcrops which I followed out

No striated boulders.

were of compact blue limestone, which, though smooth, had clearly been weathered to some extent on the surface.

Sources of the boulders.

The source of all these boulders, except the larger ones of granite and gneiss, and indeed of the material constituting the matrix, might easily be supposed to be the neighbouring transition rocks; but the crystalline fragments must have always been brought from a distance. The nearest area of crystalline rocks to any of the outcrops—leaving out those on these rocks themselves at the Godávari—is fully 16 miles away, and these are not such as would give the boulders observed: as far as I know the country to the westward, such granitic and syenitic fragments as do occur are more like the rocks of the Elgúndul country fully 70 or 80 miles off.

As will be seen on the map, the southern outcrops are not of much extent. Those I have myself visited are at Pálúncha, Dummagúdem, Singareni, and Kámawaram, and these are referred to fully enough in the Records of the Geological Survey.[1] Blanford had also previously ascertained the outcrops on the Godávari in the neighbourhood of Dummagúdem and Bhadráchalam.[2] At Sullavai, there is a much larger display of the boulder bed, and this is continued with few breaks right up to and beyond the Godávari. It is also well seen much lower down the river lying on the Chinúr and Mádapur inlier of the Sullavai sandstones.

Sullavai outcrops.

At Sullavai, the boulder bed is very clear on the road to Venkatpur, a rather fine-grained red-purple sandstone, well crowded with smoothed fragments of quartzite and limestone, among which are a few others of gneiss of large size. As it is followed down the bed of the main stream, it becomes overlaid by bands of fine sandy muds of greyish-green color and then by more decided fine-grained sandstones. Beyond Venkatpur there are frequent large boulders of pink granite among the more numerous fragments of limestone and quartzite.

In this direction, the eastern edge of the outcrop now becomes so

[1] Vol. V, pp. 46 and 65.

[2] Vol. IV, pp. 49, 59, and 107; Vol. V, p. 23. See also Manual, Part 1, p. 238.

covered up by the superficial deposits of this wide valley of Palliampet that any higher beds of the group, such as the sandstones, are entirely concealed, and thus the boulder bed or its débris is all that is met with. For the same reason, as shall be noticed further on, there is no certainty that a concealed outcrop of Barákar strata may not also occur beneath these post-pliocene clays and gravels. About Chilpur and Kotapet, however, outcrops again come in, and these again are often almost made up entirely of limestone boulders which are crowded together in a remarkable manner, there being very little of the matrix seen at all.

Much concealed in the Palliampet valley.

Towards the Mánér, the Tálchirs end abruptly, being cut off by one of the many faults of the north-north-west to south-south-east system so prevalent in this part of the field, whereby the Gondwána rocks have been thrown down to the eastward, thus bringing the Kámthis into direct juxta-position with Sullavai and Kadapah strata. A patch has, however, been left lying at a high angle at the Mánér; and then some miles further north, they crop out again and lap easily over the gneiss at the Naspur crossing of the Godávari. The continuity of outcrop is here again broken, there being a considerable shift to the eastward, on the north or left bank of the river, caused by an up-throw of the strata along a line of fault in the same system.

Cut off by faults, but eventually lap on to gneiss.

Mr. Hughes, who examined that part of the country, thus describes the outcrop as it runs northwards from Naspur:[1] "This, the lowest group of the Gondwána system, occupies a long belt of ground along the western border of the Gondwána area, in a small strip near Chinúr, and a few little patches elsewhere.

Outcrops north of the Godávari, described by Hughes.

"Its characteristic features are well seen in many sections, but the needle shales, instead of being the most prominent rocks, are quite subordinate to the sandstones. It was rare, indeed, to meet with any of the former. The boulder bed, however, is strongly developed, and in some places is the only representative of the group. This is so in the

[1] Rec. Geol. Surv. of India, Vol. XI, p. 18.

case of the little patch of Tálchirs near the boundary of the Vindhyans north of the Naogaon. The boulder bed is conspicuously exposed in the vicinity of Mádorám, and near Tándúr, and more or less continuously from Kásipúr to Naspúr. In the Godávari river, it is seen on the right bank near Sandrápali. Many of the boulders are of gneiss and of enormous size, but the generality are small, and consist mainly of Vindhyan shales, limestones, and sandstones.

"It is easy to trace the extension of the Tálchirs northwards in the direction of Chinúr by means of the boulders strewn on the surface, many of the blocks being of gneissose and granitic composition. Such, when met with, may, I think, unhesitatingly be accepted as signs of the Tálchir group, not a single instance of their occurrence in any of the other groups of the Gondwána system having ever come within the range of my experience. The doubts that assailed me as to the true horizon of the boulder bed when I first noticed it near Sandrápali were dispelled as soon as I discovered gneiss and granite boulders.

The Aknápali line of fault.

"The boundaries of the Tálchir group are almost everywhere those of original contact; but in the neighbourhood of Kásipúr, and between that village and Aknápali, there are several faults. The most distinct of them is the one that I have indicated as being probably the continuation of the faults along the west face of the Vindhyan outlier near Chinúr. It is very plainly seen a few yards below the junction of a small stream with the river shown on the map as flowing from the direction of Batwanpali towards Kásipúr. The dip of the Tálchirs is in contrast with that of the Vindhyans, the latter varying between 20° to 40° east of north, that of the former being north-westerly."

The settling of the coal question for the Madras Presidency.

Barákar Group.—The question as to the existence of coal in the Madras Presidency has always been a fertile source of much disputation out of which there necessarily arose a good deal of hope, despondency, soreness of spirit, departmental jealousy, and not a little amusement. It has only been within the last few years that the Government, or the public, has been reconciled to the fact that the only coal in the Presidency, with the

exception of a few traces of lignite in the tertiary deposits of Travancore is that contained in the few patches and outliers of Barákar sandstones situated in the Godávari district and the adjacent territory of the Nizam, and now shown altogether in the map given in this memoir.

First discoveries on the Godávari.

Desultory exploration had been attempted over and over again in the neighbourhood of Dummagúdem, but the first discoveries of coal measures were made near the mouth of the Tál river by Mr. Vanstaveren, who was then one of the Engineers on the works at Dummagúdem, through the suggestion of Mr. W. T. Blanford that search should be made there; and these led to other finds lower down the Godávari below Bhadráchalam. Somewhat later, the small field at Kámawaram in the Pákál hills was brought to notice by the Hyderabad officials, and yet later I myself came across the Singareni and Beddadanol fields, the last of which does not, as far as we yet know, contain any workable coal.

All in Barákar deposits.

All these coal measures are in Barákar strata; in fact, this is the group of the lower Gondwána series which, so far as is known, is alone coal-bearing[1] to any workable extent in the Pránhita-Godávari basin. The map will show the extent and position of the group, though it is necessary to premise that there is a long stretch of country, from some miles north of the upper Godávari reach down to Sullavai, in which no perfectly recognisable Barákars appear; though I do think—and in this I am partly borne out by Hughes—that the group is really there and merely concealed by superficial deposits.

My own experience of this group.

I have had so little experience myself of Barákar strata in their more extended areas that I can only, as it were, give descriptions of local occurrences of them; but so far they are very clearly distinguishable from the Kámthi beds overlying them, which are essentially harsh ferruginous rocks, and generally of brown or bright variegated red-purple and yellow colors, the Barákars being lighter and duller colored, white

Style and lithology.

[1] Thin seams of coal occur in beds of the upper Gondwánas in the Jángaom valley.

grey or buff, and more even-textured, but uneven bedded felspathic sandstones. They weather into rather smoother and generally large rounded exposures; and they are more usually worn in pot-holes and gullies. Large rounded ferruginous concretions are scattered through them or rather appear on their surfaces at rare intervals and stand out in warty or fungoid masses; and the many pot-holes have evidently had their beginnings in the hollows left by the concretions as they were washed out. At other times the surfaces are crowded with an extraordinary number of knobs, spheroids and grape-like assemblages of other concretions, which are, however, calcareous in their composition. With the Kámthis, there are none, or very few, of these calcareous nodular surfaces; but they are, on the other hand, very often covered with warty and fungoid knobs of ferruginous matter, and indeed very much seamed with ferruginous clays, which weather out on their edges in this way.

Hughes' experience on the Wardha.

Referring to the frequent similarities found existing between sandstones of this group and the overlying Kámthis, Hughes writes :—"It is not an easy matter to define the upper boundary of the Barákars near Chicholi, there being a most confusing similitude in the sandstones of the two series In examining the section exposed by the Wardha from Tohogaon to Sindi, Dánora and Pét,[2] there are many of the rocks which, if isolated, might have been mistaken for Barákars; but there was little difficulty in placing them, as there was a moderate margin between them and the next series. When the exact limit of that margin, however, had to be defined, the task became perplexing, and I have to confess to the possibility of my line being open to correction. In the reach of the river below Chicholi, and on the Láthi side, more strongly developed white felspathic sandstones, with a very nodular surface, looking, in every respect, like the sandstones at Télwása under the coal, is seen, which I should have had little hesitation in placing amongst the Barákars, had it not been that some

Kámthi look of Barákars.

[1] Wardha Valley Coal Field, Mem. G. S. of I., Vol. XIII, p. 62.

[2] This region is just on the northern edge of the present field.

of the beds underlying it had too much affinity of appearance to the Kámthis."

Again, at page 79 of the same work, in writing of the Kámthis in this northern portion of the field, the same writer adds:—"Sandstones occur near Sindi, having a semi-Barákar appearance, but their brownish color and a few straggling iron bands are indications of Kámthis. A seam of coal was reported to exist at Sindi; but unless the mineral character of the Kámthi series has strangely altered, no coal could possibly occur."

In passing over the same country without having previously noted the recorded observation of Hughes, I was myself also struck at once withthe Barákar look of the rocks, and I have thought it worth while drawing attention to these features which are really common to certain strata of the two groups, as there is a further strong development of them at the Pránhita-Godávari junction near Káleswar.

Out-crops in the southern part of field.

Mr. W. T. Blanford has already[1] described the outcrops on the lower portion of the Godávari at Lingála and Madaváram in some detail; and accounts of the small fields of Kámawaram, Singareni and Beddadanol were given by me later on.[2] Of the Bundalla or Bollapali outcrop, to the east of Kámawaram, we have no further details than those already given in the Economic chapter.

Style of Barákars in southern outliers.

In the Beddadanol, Kámawaram and Singareni fields the sandstones are of the usual kind, generally light-colored or white, coarse, thick-bedded felspathic sandstones with thin seams of pebbles, and showing many ferruginous concretions. The calcareous nodular form of weathering is not common.

The outcrops are generally flat-rounded spreads of thick beds; the latter do not show any particular lamination, nor are they of any lateral extent, but are irregularly lenticular and tail into and over one another. One may sometimes walk, for a mile or two, over very flat-worn surfaces, which are clean, fine, and hard, and not gravelly or

[1] Records Geol. Surv. of India, Vol. IV., pp. 49, 59, & 107.

[2] *Idem*, Vol. V., pp. 46, 65.

there ought to have been a show also of Barákars, yet there is no outcrop of beds sufficiently decided in their lithological characteristics or sufficiently devoid of certain Kámthi features to have allowed of our laying down such on the map with any degree of precision.

No decided Barákars with the Sullavai Tálchirs.

The worst of this part of the country is the wide extent of superficial deposits of the westerly valleys of the Pángadi Vágu drainage system and their wild and jungle-covered condition. One may wander for miles without knowing one's position, for a sight can seldom, if ever, be got through the tall and thickly-grown trees at hill features which have been carefully looked at from outside over the wide belt of forest, and one can only travel through this by wood-cutters' paths or by occasional tracks of sámbur or bison. Outcrops are also very rare. As it is, in working northward from Sullavai across the belt of Tálchirs and in to the base of the Gundikámáram hills, I did now and then get on sandstones which I am strongly inclined to consider as Barákars, for, though still foreign-looking, they are not so decidedly of the Kámthi type as those of the hilly mass.

Covered-up condition of the country.

Some short distance, a couple of miles or so north of the Tálchir belt, I usually met with very coarse and rough felspathic sandstones, thick-bedded, but still yellow and brown, with seams of pebbles. Dip, north or nearly so, at 10° to 30°. Strong barriers of such rock frequently crop up in the stream beds, well worn in pot-holes, just as is the case with the true Barákars at Kámawaram.

Apparent outcrops of Barákar strata.

In a traverse north-east from Sullavai, Sullavai sandstones abound in the river and are succeeded by Tálchirs but without any boundary. Next, a wide stretch of jungle-covered flat alluvial land, with much kankar[1] débris, until near the outermost low hills, where, in a bay between two spurs, are coarse grey friable sandstones and grits in thick and thin beds scattered over with débris of brown ferruginous sandstones

[1] The presence of this kankar is always very suggestive of Barákar outcrops on the ower Godávari.

and grits of the Kámthis. Dip of grey sandstones easy to north-east or east-north-east. From these there is a gradual rise over more variegated yellow and brown strata, though these are still subordinate to the grey beds, until more typical brown Kámthi beds are reached. On another traverse somewhat further eastward, very coarse harsh dirty soft sandstones occur near the river. Next, come frequent outcrops of such sandstones, and then harder more massive and thick beds, but still always rather soft, very coarse, and harsh, with small pebbles of quartz, weathering of a greenish-grey color, their real color being dirty grey or buff. These beds are coarser and rougher than is usual with Barákars, but still they are somewhat like the strata of Kámawaram. Nearing the hills the same kind of rocks are often seamed with, or have intercalations of, hard brown ferruginous clays; but just before reaching these the softer and rougher strata are of a dirty grey or greenish colored rock, having much the appearance of hardened porridge or 'stirabout' of the coarsest meal.

Barákar facies dies out to the north-north west.

Over towards Venkatpur, much the same style of rocks is continued and shows well in the higher reaches of the main stream; but they gradually lose their Barákar facies, are now very friable though still in thick and massive beds, and are very varied in color. Nevertheless, they are not true Kámthis, and I would rather suppose much of them to be perhaps thickened-out representatives of poorly developed strata in the southern outliers. Thence, northwards to the Godávari, there is less and less evidence as to a possible occurrence of coal-measures.

About eighteen miles north of this river, however, these rocks again come in with exposed coal outcrops just on the north side of the great north-west to south-east line of fault striking across the middle of the field from Waripet to the Godávari; and for this we have Mr. Hughes' description[1]:—

"The lithological features of this group are quite as characteristic here as in the Wardha Valley, and there is no difficulty in recog-

[1] Rec. Geol. Surv. of India, Vol. XI, p. 19, *et seq.*

nising the formation, where there is a fair exposure of it. But the drawback to identifying it, and tracing its boundaries, is the fact of the very incomplete sections that one has the opportunity of examining. It will be seen by looking at the map that no Barákars are shown overlying the Tálchirs between Kásipúr and Tétmatla on the left bank of the Godávari. Now, I am by no means prepared to assert that Barákars do not occur exposed at the surface; but in the absence of a single section to which I can refer as yielding undoubted evidence of the presence of Barákar strata, I have preferred to suppress the probable boundary lines which it would have been easy for me to indicate; the more so as perhaps an erroneous impression might have been conveyed respecting the possible existence of coal."

Hughes' experience north of and on the Godávari.

The most important feature about the Barákars is, of course, the occurrence of coal in them; an account of the seams has already been given in the Economic chapter of this work.

Kámthi group.—So far, though we have been treating of what is economically an important group of the upper Gondwánas, both it and the Tálchirs are, in this region, of very small account as to thickness and extent when compared with the group overlying them, which, after all, constitutes by far the greater portion of these valley deposits; for the generally very recognisable sandstones of the Kámthis are continued, with only one short break at the Jángaom valley, from the Wardha area right down to the neighbourhood of Ellore in the Godávari district.

As continued from the area on the Wardha.

For this special area full details of the rocks were long ago given by Mr. W. T. Blanford,[1] and to these can be added the observations of Mr. Hughes in his southerly extension of the Wardha valley rocks, and some further details of my own for the middle area.

The Kámthis of the Pránhita-Godávari valley are more or less throughout the field very much after the style described by Blanford, in his many papers already cited, and in the Manual of the Geology of India, that is,

[1] Rec. Geol. Surv. of India, Vol. IV, pp. 49, 82, & 107, and Vol. V, p. 23.

an immense spread and thickness of essentially brown ferruginous sandstones, conglomerates and clays; but they may be more particularly described in areas which I would call the north, middle, and southern fields, the first extending from the Wardha valley to some sixteen miles south-east of the Mánér, the next extending thence to Pálúncha, and the third lying between the latter place and Ellore or Chintalpádi.

Discussion of the field in three divisions.

The northern area.—This was examined chiefly by Mr. Hughes who thus writes of the rocks:[1]—"In the determination of this group I have been mainly guided by my experience of it in the Wardha valley coal-field. At the base we there had a series of sandstones usually coarse-grained, porous and friable, and slightly yellow, reddish-brown or grey in color; above, more compact sandstones. The character of the sandstones at the base is what I wish to draw attention to, for in several places in the area that I am describing in this paper, I have depended upon the porosity of the sandstones for the correctness of my assignment, but, of course, it must be understood only when the sandstones exhibiting the feature were at such a horizon that the analogy with the Wardha valley might be quoted to justify my having done so.

Mr. Hughes' descriptions.

"As specific rocks in the higher portion of the group, I have accepted the compact argillaceous shales and sandstones of deep red, buff and pale purple colors, they being very characteristic, both in the district from which the Kámthis derived their name, and in the Wardha valley."

Again, in describing the southern end of the Wardha field up to Chicholi:[2]—"From this point the Tálchirs are the border rocks for a considerable distance, and the Kámthis sweep round by Arwi, Jogápúr and Wirúr, occupying the right bank of the Wardha as far as the little stream between Chicholi and Antargaon. They come in again south of Anúr and constitute the hill range to Hirsni."

"Opposite Arwi are compact quartzose felspathic sandstones with

[1] Rec. Geol. Surv. of India, Vol. XI, p. 22.

[2] Mem., Geol. Surv. of India, Vol. XIII, p. 78.

scattered grains of quartz and felspar, giving them a porphyritic look. They weather with mammillary surfaces. At the mouth of the Wejgaon river, friable brown-streaked felspathic sandstones like that immediately on the coal at Ghúgús occur. To the south of this there is a fine reach of water, and opposite Súrándi compact sandstones recur. Below them in the series are friable brown sandstones. These rocks are very close to the bottom of the Kámthis, but I have associated with them the grey felspathic silicious slightly calcareous sandstone that flanks the deep pool north-west of Láthi, and some that occur a little way further down the river."[1]

"The Kámthis south of Anúr rise into high and massive-looking hills, having only a slight dip to the south. They consist of sandstones and shales. In some of the latter there is a great abundance of plant impressions, but they belong to only a few species *Phyllotheca indica*, *Schizoneura*, sp., *Glossopteris Browniana*, *Glossopteris leptoneura*. These are characteristic of the upper portion of the Damuda series in Bengal, and there can be little doubt that the rocks south of Anúr belong to our Kámthi division, and not to the Barákars.

"Near Urkúlu (Wurkoolee), east and a little south of Anúr, sandstones occur that might readily be mistaken for Vindhyans. They are of a rusty brown color, and are more granular in texture than the ordinary Kámthi sandstones. They are also more ferruginous, and have, as it were, a rougher look. I have classed them with the Kámthis, as there is no stratigraphical evidence to show that they are anything else but members of that series."[2]

My observations in this area; with regard to the sandstones of Sironcha.

I had myself an opportunity of going over this portion of Mr. Hughes' area and could thus compare the rocks with those I had seen in the middle and southern areas: but what struck me most is the extraordinary likeness which the higher beds, on the left bank of the Wardha opposite Antargaon, have to those of Sironcha. The Sironcha

[1] Mem. Geol. Surv. of India, Vol. XIII, p. 80.

[2] *Idem*, p. 81.

sandstones were always a set of rocks on which we could not quite agree, as will be seen by reference to our already cited papers in the Records, I having been in the first instance much inclined to consider them as a separate group, and belonging to the upper division of the Gondwánas.

Two sub-groups of the Kámthi division.

However, a seam of fossil plants (*Equisetaceæ*), which I found in these Antargaon beds, only further confirmed Mr. Hughes' carrying of the Kámthi outcrop across the river; and, if lithological resemblance goes for anything, which it certainly does in this area, then the Sironcha beds are decidedly—as I have at last been compelled to consider them—of Kámthi age. This was a great point gained in the relations of the sandstones of the middle region, but, besides this, it also became evident that in the whole area there are two fairly distinguishable sets of strata in the group, namely, one of open-textured and generally brown ferruginous sandstones, which underlies another of coarse sandstones, hard very compact argillaceous sandstones, and other arenaceous beds containing lumps of buff red purple and white indurated or stony clays and shales, with hard clay and shale bands of similar colors.

The fossiliferous beds of Tomta.

At the Wardha outcrop, the sandstones of Tomta run up as a series of low terraced and scarped ridges striking nearly north and south, the beds having a low dip to eastward. The village itself is on coarse, hard, light-colored sandstones, very obliquely laminated, much seamed with pebbles and fine gravel, and containing lumps of buff-colored stony clay and shale. Up towards the hill station, one passes over harsh, brown-weathering, pale white yellow and buff sandstones with ferruginous knobs and warty concretions, seams, and mammillary surfaces; having many pebbly seams, among which there is a good deal of débris of yellow chert. About a hundred yards down the eastern slope, there are irregular seams of pink white and purple laminated clayey shales and sandy shales, with laminæ of matted *equisetaceous* stems and rare leaves of *Glossopteris*. The surfaces of these shales are also quite hard and rather glazed or porcelainised; though this condition is really a result of

weathering. The Tomta beds are succeeded by the red clays of Porsa, further down the river, which belong to the upper Gondwánas.

The Western outcrop.

The two varieties or sets of Kámthi rocks of the Wardha valley, namely, the lower brown ferruginous sandstones and these upper lighter-colored and more argillaceous beds of Tomta are now continued southwards past Sirpur, after which village the upper beds disappear or are covered up, while the lower and more typical beds keep on and bay round to the westward in the Jángaom valley where they are overlapped also by the upper Gondwánas.

In the neighbourhood of Aodam.

On the south side of this valley they again appear and continue past Tándúr to the Aknápali line, of north-west to south-east faulting, and it is to this portion of the field that Hughes refers in his last published paper. Between Tándúr and this fault line, or in the neighbourhood of Aodam and to the eastward, the upper variegated and lighter colored sandstones, with more or less argillaceous seams and fragments, show in great force and are continued on—though now left somewhat to the westward on the downthrow side of the fault—in the gradually rising ridges to the east of Narwar and Narsingpur which strike away south-east across the rivers as far as Metpali, where they die down or lose their definition in the Korlakunta and Kamlapur country. Thus far also the upper beds are very well displayed, but no more of them is seen in that direction, the few outcrops exposed in the low lying and covered up ground to the south having more of the characters of the lower brown beds; a break of continuity which only seems explainable on the occurrence of a hidden system of faults partly parallel to the main one of Aknápali. Further, the lower brown and red beds are also continued with tolerable distinctness as far south-east as the left or north bank of the Godávari; but, south of this, the strata are really so different in many respects that I think the lowest band of the Tándúr beds is cut off also by a line of fault which would appear to be striking more or less in the river bed past the break and shift of boundaries at Naspur.

Break in continuity of beds about the Mánér.

The upper sub-group in the Somnapali ridges.

The southern end of this northern field, between the two rivers, at Somnapali and Aravi-Somnapali, was also visited by me, and here the upper member of the group forms a rather fine and lofty set of craggy ridges with broken escarpments facing northwards and the usual long dip slopes leading down to the two Somnapalis. There must be an exhibition of the true thickness of a portion of the series in these ridges, for I could see no indications of any repetition by throws, and this must be at least 1,600 feet, the dip being on the average about 10° to the north-east.

Thickness.

Style and lithology.

To the west of Aravi-Somnapali and on the north side of the pass of the Mánér through this ridge, the dip slope is of thick-bedded harsh red, reddish yellow, and yellow sandstones with thin seams and bands of hard red and brown ferruginous clays, also many bands of thinner-bedded hard ferruginous grit, semi-vitreous, filled with small pebbles and gravel of quartz and quartzite. Lower than these, and forming the upper part of the escarpment, are brown sandstones and beds of red and purple clays and other argillaceous sandy beds which are sometimes crowded in the most extraordinary way with lumps of buff and purple indurated clay and shale. Lower down the escarpment there are several thick beds of vitrified sandstone which look rather like quartzites, but they are subordinate to the ordinary sandstones with clay galls. Still lower, an outer ridge at the base is made up of salmon-colored red sandstones which are the northerly extension of the Tárcherla sandstones referred to in Hughes' and my papers in the Records, and which I at one time thought were the same as the Vindhyan sandstones of Sullavai.

Obscure beds in the low country to west.

Out in the low country of Mantani below the western scarps, there is a belt of covered-up rocks giving no good sections or outcrops, or offering any clue to their proper relations with those to the north or southward. Such rocks as are seen are generally thick-bedded, rather smooth-textured, grey and light-colored sandstones which are sometimes calcareous, and they have

generally a very Barákar look. Mr. Hughes visited this region, and in the neighbourhood of the above village found some fragments of *Glossopteris*; but he does not remark that the strata here differ in any decided way from those he found going northward towards Tándúr. It seems to me, on the whole, that there is here a thickening out of a rather calcareous form of sandstones which has not hitherto been observed in any force to the north, and that the brown beds have been largely denuded and cut off by faulting along the western boundary on the Mánér.

The thickness of the Mantani portion is not so easily computed as that of the ridges; but it may be about 1,200 feet, thus giving for much of the north-westward outcrop of the Kámthis a thickness of 3,200 feet.

A like set of rocks lower down river at Káleswar.

Very nearly the same succession of rocks occurs again further down the Godávari in the neighbourhood of Chinúr, Káleswar, and Sironcha; and thence the upper argillaceous and shaly band, or what we have usually called the Sironcha sandstones, is traceable, though with many breaks, southwards by Madapur, the Partabgiri hill, and so by the eastern flanks of the Gundikámáram hills down to Palúncha. The Káleswar region is much obscured by the alluvial deposits of the great river, and there is local faulting, but the main succession is clear, from the brown ferruginous, harsh and coarse sandstones of Káleswar, overlying the probable coal-bearing Barákars of Sandrápali, up through the lighter colored and rather calcareous beds of Nágram on the opposite or left bank of the river to the thick series of variegated sandstones and red ferruginous argillaceous strata of Sironcha, which, as already stated, correspond most closely with the fossiliferous beds of Tomta on the Wardha.

The Káleswar outcrops.

A description of the outcrops on the Pránhita-Godávari junction will also illustrate some of the characteristics of these passage beds, with a calcareous constitution, between the brown series and the more typical argillaceous sub-division of Sironcha. Káleswar is on a low ridge of coarse harsh open-textured brown and red ferruginous sandstone, with hard ferruginous clayey seams

ridging the surfaces, of true Kámthi type, which are succeeded in the bank of the river to the north by further brown or dark grey sandstones, not so ferruginous. These curve round to the north-west and westward by the village of Puskapali; and then there is a break or blank of alluvium, until immediately north of that place there is an outcrop, about ten feet thick, of strange sandstones made up in great part of small and large pieces of yellow calcareous clay crowded together in a thinly distributed matrix of dark-colored quartz sand. Dip about 20° due east, altogether out of the usual lie. Further west, there are intermittent outcrops of ordinary Kámthi beds. On the Raolapali side and opposite, there is a larger show of rocks filling up about half the width of the river. First of all, and most southerly and easterly, a strong ridge of yellow and grey rather fine-grained rough sandstone, much water-worn, with sharp outlines and scabrous with seams and patches of hard brown iron-infiltrated gravels pebbles and clays. The bedding of this island outcrop is not very constant or distinct, the strata rolling about at every angle, but on its north side the dip is to the north. On the shore, and consequently higher in the series, are strong outcrops of sandstone in north-west to south-east bars, and the most westerly of these is of irregular thin-bedded sands and greenish-grey clays, undulating above a bottom bed of greenish argillaceous sandstone. Some of the beds in this bar are also crowded with pellets and lumps of green clay like that near Puskapali Over these there follows, in the succeeding bars along this bank, a regular succession of extremely false-bedded grey and buff softish sandstones very pebbly themselves, but with bands also of gravel, with which are intercalated hard brown ferruginous grits and seams of brown iron clays. Many of the less ferruginous beds also show a good deal of the nodular form of weathering, similar to that described by Hughes for the Wardha valley beds. These Raolapali beds are striking at, and are evidently continued in, the Káleswar point of the river bank where rocks are only seen again after an interval of alluvium. Here, still higher in the succession, come many more beds of false-bedded sandstones, yellow and brown, micaceous, shaly and flaggy strata, with harder bands, and, still

higher, fine soft sandstones and shales which are succeeded at the low water edge by soft clays of dirty brown color. South of the point, in the river bank, much the same series is striking along in curved and straight bars, but with many cases of local overlap and also of sudden changes to high dips from the normal easy lie, accompanied by crushing and strong infiltrations of ferruginous and silicious matter along lines of what appear to be local and small faults. A fair computation cannot, therefore, be made of the thickness of these abnormal strata, but the greatest thickness I could reckon on at the point can scarcely be more than 100 feet, if so much.

There is then a wide blank in the bed of the river, no more rocks appearing until the opposite bank is reached at Nágram where there is an outcrop of thick massive beds of dirty-grey, rather smoother surfaced but still coarse, slightly calcareous sandstones, with seams of green and yellowish clay-galls, which answer very well to the thick beds in the Mantani doab below the upper argillaceous banded sandstones of the Somnapali ridges. The river bed can, however, without much doubt be considered as filled by beds similar to those found here and there in the bars further down its course, which are dirty grey and brown pebbly sandstones, gradually succeeded on the left bank by more massive and smooth somewhat calcareous strata.

From Nágram.

At the Nágram point, the uppermost thick bed of the outcrop is in turn succeeded by obliquely laminated coarse gravelly beds, and then again, after an interval, by other massive though thinner beds with clay-galls and fragments of purple shale. Over them come thick irregular beds of soft yellow brown and variegated sandstones, some of which are so soft as to be riddled with the tubes of the boring spider commonly seen in the outcrops of the much softer upper Gondwána strata above Sironcha.

To Sironcha town.

There is now a long blank of about half a mile of alluvium on the left bank of the Pránhita, and then comes a continuous succession of the Sironcha beds in low cliffs and headlands all the way up to the town which are very like

those of the Somnapali ridges and those of Tomta on the Wardha river. In this long outcrop, there are two harder and more ferruginous bands or sets of beds which give strong ridgy outcrops, on the chief and uppermost of which the town of Sironcha stands. The few bungalows of the station are built on the highest part of this as it strikes away inland from the river bank in a south-east direction, the beds having a dip of from 10° to 15° north-east. Here, the sandstones are seamed with strong runs of pebbles and gravel, and with red purple and lilacstony clays none of which are very constant for any length of strike but appear and thin out every now and then in the most capricious manner. For example, in the headland overlooking the river on which the old fort is built, there is a four to five feet bed of stony clay at the south-west bastion which runs down to only a few inches in thickness at the water-gate. Other, but less thick beds form portions of the north-east slope of the headland, where they roll down in dip-slopes among very massive and thick-bedded dirty brown and purple sandstones which are themselves scarcely less variable in their continuity.

Away to the north-east of the town, there is a dip down to the alluvial plain, and no further rocks are seen; but more inland, the more argillaceous banded sandstones are overlaid by a thick series of generally ferruginous sandstones and pebbly beds: and this completes the succession so far as we know it here, for at a short distance further north-eastward a band of limestone is met with which belongs to the Upper Gondwánas.

The Sironcha beds on the right bank of the Pránhita.

The Sironcha ridge beds appear again on the right or opposite bank of the river and run up as the Arjungúta hill station in which low ridge they end, as to their strike, abruptly against Upper Gondwána beds by an east-north-east to west-north-west cross-fault. In some respects the beds of the hill station differ very considerably from those of the Sironcha ridge and look really more like Kámthi strata, but close examination showed that these brown and very often hard semi-vitreous sandstones

are merely locally altered beds, while the purple and red and buff clays run on with them.

Fossils supposed to have been found in Sironcha beds.

I was not able to find any recognisable fossils in the Sironcha outcrops, though there are traces of minute vegetable matter in the form of twigs and débris which seemed to me to be very like other plant débris of upper Gondwána age occurring beyond the Arjungúta hill station at Anáram. It appears, however, that some better remains were once found here, possibly like and similar to those found at Tomta, for it is mentioned in a note[1] of the Revd. Mr. Hislop that "in the sandstone at Sironcha, 6 miles further down the river Pránhita, there is an abundance of compressed stems identical with those of Silewáda; so that there can be no doubt that the argillaceous sandstone there is of the Damúda group."

Thickness of the Káleswar-Sironcha strata.

The thickness of the Kámthis in the Káleswar-Sironcha area must be very much the same as it is in the Mantani doab, or from 3,200 to 3,500 feet.

Faulted at northward.

The Sironcha-Nágram belt is cut off abruptly to the south-east by a very clear east-north-east to west-south-west line of fault, a short distance north of Ardium, which is very much in line with the abrupt southerly terminations, or dyings out, of the northern outcrops of the Kámthis on the right bank of the Godávari below Madapur and away in the Somnapali ridges. On the south or down-throw side of the Ardium-Madapur line, the upper strata of the Kámthis are thrown considerably to the westward, and then strike away south-eastward by the Partábgiri hill which shows a clear thickness of a portion of these beds of at least 1,000 feet, a considerable thickness of their lower portion being hidden in the talus at the base and out in the western low country. Thence they strike on in the long ridges of Jilapili and Nándigaom, flanking the eastern side of the Gundikámáram hills and so across the Pángadi Vágu into the Kátapur hills west of Mangapet. All

Extension southward in the Partábgiri hill.

[1] Proc. Geol. Soc., London, Vol. XVIII, p. 36, 1861.

this time, the average lie and thickness of the upper portion is preserved, and it consists of the same coarse, often thick-bedded sandstone, with subordinate bands of coarse, gravelly sandstone, having very frequent clay bands, and runs of clay fragments.

South of the Pángadi Vágu, the same series becomes much more spread out, the dip, in places, becoming correspondingly low, until the great stretch of country between the head waters of the Kinarsáni stream and the Godávari appears to be entirely made up of this red and buff clay banded series.

The middle area.—As already stated, the Mantani strata die out, or end rather abruptly; at least, this is the case more especially with the Somnapali beds at Korlakúnta beyond which place they are not traceable with any clearness. There is, in fact, in this direction a low-lying jungle-covered tract, much obscured also by superficial deposits, with only few and isolated outcrops of various sandstones which cannot be placed very definitely in either the upper or lower portions of the Kámthis. Sometimes, there are tolerably smooth-surfaced sandstones with a slightly calcareous constitution answering to those of Tárcherla in the Mantani country, or of Nágram; while again there are open-textured harsh yellow and brown sandstones of the lower portion of the series; or there are bands of argillaceous sandstones with clay bands and seams of clay-galls and other fragments. Generally the brown strata are commonest.

Covered up tract between the Mánér and the Gundikámáram hills.

To the south of this low-lying tract, there is then the large hilly mass of Gundikámáram; and this consists either of an immense thickness, or, as I prefer to think, a lesser thickness, exaggerated perhaps by step faults, of frequently alternating bands of hard ferruginous brown and reddish-brown sandstones, and more uniform but thicker bedded grey and buff strata, having generally an easy dip of 10° to 20° east-north-east. At times the dip is high, 50°—60°, but generally it is low, and in the middle of the range the beds are often horizontal.

The Gundikámáram tract.

The harder and harsher-textured brown beds are strongly banded

in the lamination, or again seamed across this, with ferruginous clay, and often crowded with concretionary masses of all shapes and sizes which stand out as nodules, bunches and fungoid forms. In fact, it may be said, that these warty and nodular sandstones are as characteristic of the lower portion of the series as the clay-banded fragmental beds are of the upper division.

The hill range, being made up of these alternating rough and thick beds, is characterised by very rugged and irregularly worn ridges and headlands running between smoother surfaced belts of less hilly ground.

Style of rocks on a traverse across strike.

On the western side of the range, the strata of the Palliampet valley are gradually overlaid by dark brown-weathered, coarse brown and grey felspathic sandstones and grits with thin seams of pebbles, and above these come very thick strata of coarse grits with some intercalated harder and thinner beds, or sometimes rather vitreous flaggy brown strata. The thicker beds have seams or bands also of hard brown and reddish-purple clayey material; though all these very hard clay bands are, for the most part, only so hard at the outcrop, the induration being mainly a result of weathering. All these beds form the outer western ridges, and they are dipping at 15° to 20° north-north-east giving a thickness of four or five hundred feet. Their easy dip-slopes range far away to the north-eastward into a wild and trackless jungle which covers up still higher sandstones of much the same style, but now with well-marked and thick belts of the ferruginous banded and warty beds, as far as the village of Gundikámáram, beyond which is a wide stretch of low-lying country, with very few steady outcrops of rock, up to the base of the Nándigaom ridges, which are of the upper more argillaceous sub-division.

Further south, the flat level between Gundikámarám and Nándigaom narrows rapidly, the hills trending round more to the south-east and running down to the Pángadi Vágu near Urawattam and Narainpur, thus fetching their eastern outcrops close against, or under, the clay-banded beds of the first village. In working westward from Narainpur, there

are in the low grounds frequent though small out-crops of coarse grey and buff sandstone, having rather a Barákar facies, with occasional brown beds; dip 10° to 20° northward. Then, as the ground rises, loose brown beds are met with, and then a low terrace whose eastern face is edged with more indurated or vitrified beds of the same kind. Dip 20° north-north-east. Next, up a steeper slope of the main ridge over brown and grey beds, and lastly on to reddish brown, very dark, coarse hard sandstones with weathered ferruginous surfaces and other surfaces crowded with the warty and fungus-like concretions. These beds form the face of a further high terrace which is very flatly denuded and has a most strange look among such high dipping beds, for its strata appear to be lying nearly flat through being laminated or bedded, as it were, by numerous seams of ferruginous infiltration which are running across the bedding at a much lower angle, while there is a great deal of false bedding and oblique lamination which sometimes seems to be running with this. The terrace is of grey-buff and brown coarse sandstones with frequent seams of pebbles and pebbly gravels which are really the best guide to the true stratification of an otherwise strongly seamed set of strata. At the back or west of the terrace there is then a high ridge which is made up of a belt of the harder ferruginous brown beds, and these run up to the north-west as the ridges immediately behind Gundikámáram.

Style of rocks succeeding the Gundikámáram ridge.

The dip varies so much across the whole range that it is very difficult to estimate the probable thickness of the lower division of the series as represented in those hills; but I take it on an average as at about 8°, and this alone would give, on the horizontal width, a serial thickness of over 7,000 feet, which is certainly a very remarkable thickening-out from what is shown on the Godávari above Káleswar. To the southward, in the Bundalla hills, the same style of rocks is continued, with a steadier strike and lie, but there is again a narrowing of the belt; and this steadiness of strike and lie in the northern and southern edges of the middle area, as

Thickness of lower sub-division.

against the irregular dip in the large hill mass, leads me to look on the Gundikámáram outcrops as showing an exaggerated thickness of the series.

Bundalla and Kátapur outcrops.

The Bundalla ridge is made up of brown-yellow and red-purple coarse friable sandstones and grits with frequent ferruginous clayey bands, having an easy dip to eastward, which indeed is the slope of the range on that side. At the foot of this dip slope there is a wide valley of alluvial deposits and beyond there is a further succession of scarped hills which gradually get lower and lower until the wide plain of Mangapet is reached. The sandstones of these inner ridges are all of lower Kámthi type until the outer ridges of Kátapur are reached, and then the clay-banded series with sandstones loaded with fragments of clay comes in and forms all the Mangapet country, higher and exceedingly shingly and gravelly beds being found in the outlying Nursingúta plateau close to the river bank.

Intercalation of strip of Barákars by faulting.

The rocks of this region are not, however, all of the Kámthi group for an outcrop of coal-measures was discovered here by Mr. Heenan of the Nizam's mining service right in among the beds of both sides of the Bundalla valley, which shows also that this region is not free from local faulting. Indeed, there are several indications in this neighbourhood of considerable fracture and displacement of the rock groups. The Bundalla strip of Barákars can only have been brought in by faulting apparently along a north-north-west to south-south-east line, and such a dislocation is, in part, borne out by the existence of perennial springs of water further north beyond the watershed separating the Kinarsáni and Mangapet river drainage. All this part of the country is usually dry, would indeed be entirely dried up in the hot weather if it were not for these remarkable sources of water, for the lie of the sandstones is just such as to facilitate absorption of water along the bed planes. These springs rise in the valley about six miles north of Bundalla and send a fair supply of beautifully clear and good water down the otherwise very dry drainage

Lines of water springs.

area; and a further set of springs occurs still more to the north-east in the Kondaparti valley, where for short distances there are several lovely green oases of vegetation, under the grateful shade of which one can camp beside the shallow reaches of clear water, and forget that outside and all around is the bare and leafless jungle and dried up country over which are sweeping the parching blasts of May.

Local displacement.

Between Bundalla and Kondaparti there are frequent cases of local faulting in general north and south lines in which the displacement is shown by the most clear juxtaposition of different sets of sandstones and gravels against each other with the accompaniment of turned up ends or edges of the beds, slickensided faces, and nearly always strong ferruginous and silicious infiltration. These local lines of fault have generally a somewhat curved strike ranging between north-west to south-east and west-north-west to east-north-east lines, with a high dip to south-west. A short distance to the north-north-west of Kondaparti there is a remarkable outcrop of green red and white clayey strata, right in the middle of the Kámthis, or rather in their upper portion, which are presumably beds of the red-clay series in the Upper Gondwánas, and which must be let in here by faulting. I know myself of no beds like these anywhere in the Kámthi group.

Interposition of a patch of Maleri clays.

The southern field.—The brown ferruginous iron-clay banded and nodular lower member of the group is now continued south-eastward into the Pálúncha region, and so past Chintalpudi until they disappear under the upper Gondwánas of the coastal region.

Chintalpudi outcrops of upper sub-division.

In the Chintalpudi part of the country, however, there is a good development of the variegated and clay-banded upper division of the group, which answers very well to the beds of Sironcha. In the early days of my examination of this area I thought myself that a local grouping of the rocks into the Chintalpudi beds and a higher Dummapet band might have been made out, but I did not afterwards meet with any further representative of the Dummapet beds in the more

extended region; these must, therefore, be left for the present as a part of the upper division.

Fossils.

Plant-remains were found in this southern region at Kunlacheru and Somavaram in beds which belong, to all appearance, to the lower portion of the upper subdivision of these Kámthis. The fossils are *Vertebraria*, *Glossopteris*, and *Phyllotheca*, from fine clayey sandstones and pinkish or buff indurated clay beds associated with coarse harsh grey and buff sandstones.

The lower brown and ferruginous banded and nodular beds occur more on the eastern side of the Chintalpudi hills between Kotakámarapúkota and Nagawaram, having on that side of the country haded up from under the more variegated and light-colored clay-banded series.

CHAPTER VIII.—THE UPPER GONDWANAS.

Already known at southern end of the field.

In the southern portion of the field just referred to, the Kámthis are overlaid unconformably by ferruginous sandstones of Rájmahál age belonging to a distinct, sometimes marine, series which is only developed on this side of India for a certain length along the Coromandel, and which is more fully described in a previous memoir. (Vol. XIII, part 3.)

Northern development.

The next nearest development of rocks of the upper division of the Gondwánas occurs far up the Godávari, a few miles north of Mangapet, but it is here, like the lower division, essentially a river and lacustrine series of arenaceous clayey and in a subordinate degree, limestone rocks. The fossils of one of the groups are also common to the Rájmahál and Jabalpúr floras in their typical localities and in the lower Godávari district.

Their relation with the lower division obscure.

The settling of the relations of this series with the underlying Kámthis, and the relations, of its groups among themselves, has, however, for many reasons, been a matter of considerable difficulty necessitating long and repeated examination of the rocks; and even yet, as far as it

§ 34, this is not so complete as one should wish. Locally the separation from the Kámthis does not appear to be very marked, and there is a certain amount of similarity in their lithological constitution; but, taken as a whole throughout the field, unconformity by overlap is then very evident. For instance, opposite Sironcha, near the Arjungúta hill station, strata of the newer series are resting on beds of the upper sub-division of the Kámthis, while a few miles further north-west, the rusty brown beds of the lower Kámthis are succeeded by lower strata of the same series, and still further northward, these last are found to be lying on the lighter colored argillaceous sandstone of the upper sub-division. Again, in the Jángaom valley, there is the strongest possible overlap of these rocks on to the lower division of the Kámthis.

Mainly unconformity of overlap.

The work done on these rocks, and the literature describing them, has extended over a long period from about 1841 up to last year when I concluded the examination of the field. In the beginning, Dr. Walker discovered fish remains in the beds of Kota, a small village north of Sironcha; and many years later the Revd. Mr. Hislop of Nágpur brought to notice the occurrence of fish teeth and reptilian bones in the red clays of Maleri. At various times since then, Mr. Philip Wall, Messrs. W. T. Blanford, Fedden, Hughes, and myself have worked at and described the rocks.

The working out of the series.

The series nominally consists of three groups, the uppermost of which is, however, less closely related to the other than they are among themselves, for which reason I have still very serious misgivings as to its properly belonging to this series. They are in descending order:—

Its grouping.

Chikiála Group.
Kota „
Maleri „

Mr. Hughes is very much inclined to consider that the Kotas and Maleris are one group, which he would designate as the Kota-Maleri member; but I think there is quite sufficient evidence to show that

these are separable on lithological and stratigraphical grounds, as well as by their fossil contents. Early in the study of these rocks I was led to look on the upper group as representative of the Tripati sandstones of the marine jurassic series on the coastal region of the Godávari from their lithological similarity; but it will be better to let this correlation remain in abeyance until further evidence as to their age is forthcoming.

The Maleri group.—This is essentially a series of variegated, light-colored, open-textured and rather soft sandstones, with very many bands of bright red clays, and it is named from the village of Maleri or Maledi which is on the greatest show of red clays and close to the locality whence the original fossil teeth and bones were obtained. This group is only developed over the western portion of the field; namely, on the Wardha at Porsa, in the valley of the Jángaom river, and thence south-eastward to within a few miles of Sironcha and again around Angrezpali, on the Chinúr reach of the Godávari. To the eastward, it is covered up by the Kotas which stretch in a continuous but broken belt from the Wardha valley to below Enchapali on the Godávari.

General character and extent.

Hughes gives a short description (*l. c.* p. 81) of this group, as it is seen on the northern edge of the field, in the neighbourhood of Porsa, on the right bank of the Wardha:—"Fine-grained sandy beds, light grey, with streaks and blotches of red, occasional large particles of felspar scattered through the mass; beds coarser than the former, somewhat pisolitic, considerably argillaceous; greenish-grey fine-grained sillicio-argillaceous sandstones, slightly calcareous, with green clay-galls. Above these beds, and jutting some way into the river, is a compact grey sandstone that at some distance off looks like a Barákar rock; but on breaking it, green and red clay-galls are found in it. These clay-galls are very decisive indices. A peculiar sandstone that occurs is a frosty-looking bed, preparing, as it were, to effloresce; color, greyish-white." Further down the river, the red clays are in great force, in low bars, jutting into or cropping up in the water. In the Bápur nala, there are red and green clays in separate

Hughes' account of the Wardha outcrops.

beds or interlaminated in the same bed, sandstones with a granular texture, greyish-green in color with small dashes of red clay, and white unctuous sandstones.

Extension into proper field of Maleri.

The red and occasional greenish clays are traceable southwards by Sirpur and Chichpali into the Jángaom valley where they become overlapped by beds of the higher group, though there is just a small outcrop of these near Andeli on the river bank. Then a short distance south, the group again hades out from under a strong band of sandstones which is best seen at Gungapur; and away north-eastward there is a great spread of the more typical red clay part of the group, extending to within about eight miles of Sironcha, at Isnai, where they are again overlapped by beds of the Kota group. In the northern portion of this area there is a fair series, displayed more especially about Nambála and Achlapur, of north-eastward dipping, red clay bands with their arenaceous intercalations and many bands of grey rubbly calcareous sandstone containing lumps of dark red chocolate-colored and greenish clays.

The eastern boundary.

The eastern edge of the clay basin runs from a little north of Naogaom past Gungapar, Wadola, Kasnapali, and Nakalapali to Isnai tank; and along it the red clays suddenly become less persistent and are succeeded by variegated sandstones with intercalated or subordinate bands of clay. Over these again comes a thick set of thick-bedded sandstones which I consider to belong rather to the Kota group, and which, as a matter of convenience, I will write of as the Gungapur beds as being at that place well exposed in fine cliffs of forty or fifty feet in height.

At Maleri.

All round the village of Maleri there are bright red and vermilion colored clays, showing very rarely in sections, and then only very poorly bedded and laminated. Generally, these clays show merely as wide undulating fields of red clayey soil which has been smoothed down by weathering and cultivation; and it is on the surfaces of these fields or in the runnels and *nálas* that the fossils characterising them have been found. I do not think a single fossil

has been found *in situ*, but most of them have still the red clay attached, or also a little coarse rubbly calcareous grey sandstone. This rubbly rock occurs in patches and seams among the clays, mostly low in them; and the lowest beds of the group in this valley are generally of such grey rock. The fossils appeared to me to have been derived from the lower portion of the clays for the most part, though it is probable that they occur, here and there, throughout the group, only always in the middle area.

No fossils found *in situ*.

In the south-east part of the basin, that is about Naneála, the bottom beds are yellow and red friable sandstones with purple sandy clay bands, and these gradually change upwards into dirtier beds with red and green clay-galls, slightly calcareous, until the more calcareous grey rubbly rock with red and green clay-galls is reached. These last are not of any thickness, though there must be separate beds of two to three feet. Then the red clays come in, with gradually thinning bands of the calcareous rock.

Style of the rocks in the southern portion of field.

Further north these rubbly beds become more persistent and definite as in the very decided red clay area between Achlapur and Nambála, where there are several ridged and parallel outcrops of such rocks in fair beds of a few inches or a foot and a half in thickness, forming bands of varying width up to ten or twenty feet, and dipping at 10° or 15° north-north-east. They are still subordinate to the clays, the whole width of the field here being made up of belts of red clays with four much narrower bands of the grey beds.

In the northern portion.

About half-way between these two villages, and just north of Balánpur, the red clays lie directly but unconformably on gravelly sandstones of the Kámthi group without any subjacent calcareous grits. The clays are lapping round a low ridge of brown and yellow false-bedded sandstones with many layers of yellow and white quartz pebbles or, in fact, fine gravels; good hard yellow and brown gravelly beds, with the unmistakeable dark-brown ferruginous clay bands, and warty concretions.

Unconformity of clays on Kámthis.

In a section across the strike from Nambála past Daramál[1] and on towards Itála, there are four bands of the calcareous rubbly beds, the first village being on the lowest and the latter on the highest of them, and above this last come more red clays associated with sandstones which are then succeeded by ferruginous and non-calcareous sandstones belonging to the Gungapur band. There must be a succession in this section of over 2,000 feet of the Maleris; but this is the only part of the field where anything like a section of the group occurs. I think, from what is seen of it in other parts, that this thickness must be exceptional to some extent and that the thickness of the group varies very much, there being, every now and then, indications of undulations as over an uneven bottom of the Kámthi sandstones.

Succession of the beds at Nambála.

No fossils were found in the northern portion of the field, or indeed anywhere else but in the middle ground and in the Angrezpali outlier on the Godávari, though this may be in part accounted for on the supposition that these remains may be thinly scattered through the clays, while the flatter lie of the beds near Maleri gave freer scope to denudation of a particular fossil bed. Virápa, the native collector sent down here by Mr. Hislop in the first instance, must have made some clean sweepings of this remarkable field, working as he did over untrodden ground. We only came a few years later, before there had been time for fresh accumulations to be gathered to any extent in the gullies or on the fields; nevertheless, thanks to a novel mode of beating across these fields with his men in a long line at a few yards from each other, Mr. Hughes managed to pick up many good things, and, only a few months later, when we went over the same ground together on a similar beat, our search was rewarded with some teeth of the *Ceratodus* and some fine bones of the *Parasuchian* crocodile.

Mode of occurrence, and restricted area of fossils.

The commonest remains are coprolites which lie about the fields in

[1] Not marked in the map, but situated about three miles north-north-east of Nambála.

large numbers, of all sizes and shapes, from the short cylindrical form with tapering ends and spiral foldings up to large flat rudely discoid coils. Next in frequency come the teeth of *Ceratodus*, and then vertebræ and fragments of bones, scales and jaws, with teeth of the crocodilian. A complete examination of these remains has not yet been made, but, as far as is known at present, they consist of—

Fauna.

PISCES.

Ceratodus hunteriánus.
„ *hislopeanus.*
„ *virapa.*

REPTILIA.

Hyperodapedon, sp.
Parasuchus, sp.

The occurrence of *Ceratodus* teeth was originally discussed[1] by Dr. Oldham; but they are last described by Professor L. C. Miall in a memoir[2] on the genus, wherein it is stated that he does not consider it desirable to disturb the nomenclature and arrangement provisionally adopted by Dr. Oldham, the additions made to the collection not being yet sufficient to allow of the species being defined with certainty. Then, as to the age of the rocks, the same author writes—"The Maledi *Ceratodontes* are derived from rocks reputed upper Triassic on palæontological grounds."

The evidence of the fauna as to the age of the deposit. Prof. L. C. Miall.

In the same fasciculus of the Palæontologia Indica, Mr. Blanford has contributed a paper "On the stratigraphy and homotaxis of the Kota-Maledi (Maleri) deposits," in which, as a preliminary, he discusses the question of the fossils having in no case been found *in situ*, and comes to the conclusion that they must really, as all along supposed, have been derived from the clays. The following extracts will be interesting to the reader of the present

W. T. Blanford.

[1] Mem. Geol. Surv. of India, Vol. I, p. 295 (1859).
[2] Palæontologia Indica, Ser. IV, 2.

work as showing what is known of these most curious fish and reptilians, and the evidence as to their geological age :—

Triassic facies.

"The genus *Ceratodus*, as was originally noticed by Dr. Oldham when describing the first specimens obtained by Mr. Hislop, and, as is shown by Mr. Miall in the accompanying description, is in Europe chiefly characteristic of triassic and rhætic beds, a solitary instance being on record of the occurrence of this type in jurassic strata. The teeth found at Maleri closely resemble in shape some European triassic forms. The genus *Hyperodapedon* is, in Europe, purely triassic, and the Parasuchian crocodilians are almost confined to the trias, a few remains having been found, in Germany, in rhætic beds. The evidence in favor of triassic age for the beds of Maleri is, therefore, very strong, and it is confirmed by the circumstance that there is a well-marked resemblance in mineral character between the rocks from which the fossils are derived at Maleri and the Panchet beds of Bengal, and that the latter have furnished triassic and rhætic forms of plants, together with Dicynodont reptiles and Labyrinthodont amphibians, all of which may very possibly be of older mesozoic type.

Incidental reference to Kota beds.

"The relations of the Kota fish to European lower jurassic forms are no less marked than the connection between the Maleri fossils and remains found in European triassic rocks. It is unnecessary to do more than refer to the evidence given in the accompanying descriptions by Sir P. Egerton. Of nine species of fish now known to occur in the Kota limestones, four belong to typically liassic genera, and the remaining five to a genus well represented in the European lias. Of the other Kota fossils, an *Estheria* and a *Candona* have been described by Professor T. Rupert Jones, but these Entomostraca, although they are in no respect opposed to the evidence of age afforded by the remains of fish, do not in themselves furnish much aid in determining the relations of the fauna, because species allied to them are found in beds of very different geological epochs.

"Our knowledge as to the relations of the rocks at Kota and Maleri stood thus until about two years ago,—the Maleri beds being considered triassic, and being supposed to represent the Panchets of Bengal, whilst the Kota limestone was believed to be on a higher horizon equivalent to that of the European lias. My own traverse of the country in 1867, and a still more hurried visit in 1870, cannot be said to have afforded much evidence as to the relations of the beds. I obtained fossils at both places, it is true, and, as I thought, satisfactorily identified the Maleri beds with the Panchets; but I was unable to trace the stratigraphical connection between the beds at Kota and those of Maleri. It should be explained that, owing partly to the tendency of the Gondwána beds, and especially of the higher groups, to disintegrate at the surface, and to form a thick mass of sandy soil and subsoil, which conceals all the beds, partly to the flatness of the country,—a circumstance in itself connected with the deficiency of hard bands of rock—partly to the existence of thick and widely spread deposits, probably of fluviatile origin, and partly to the prevalence of forest, the tract of country around Maleri and Kota presents unusual difficulties to the geologist. Even in the streams, it is very rare to find good or continuous sections; everything is masked and concealed by surface accumulations of sand, clay, and gravel. In the course of many years I have never been in a country in which the rocks are traced with greater difficulty than in the Godávari valley.

Difficulties in the way of following out the separate groups.

"In the seasons 1875-76 it became at length possible to examine the Godávari country around Sironcha in more detail than had hitherto been practicable. Mr. Hughes had completed the survey of the Wardha field forming the north-western extension of the great tract of sedimentary beds in the Godávari valley. Whilst Mr. King had brought the geological lines to the same neighbourhood from the direction of the coast to the south-east. A considerable area of Gondwána rocks still remains to be mapped, but in the course of the past two seasons the country around the Pránhita has been completed by Mr. Hughes. The

Our early views of their relations.

neighbourhood of Kota and Maléri has also been examined by Mr. King, and both geologists agree in considering that, although the bed of limestone at Kota is higher in position than the clays at Maleri, the former can only be considered a band intercalated in the latter, no break being traceable between the two beds, whilst clays precisely similar to those of Maleri are found above the Kota limestone, as well as beneath it. At the same time, as already mentioned, remains of *Hyperodapedon* and *Parasuchian* crocodiles have been found at several other localities besides Maleri; and, although, owing to the difficulty of tracing the different strata across the country, it is by no means easy in all cases to determine the exact relative horizon of any bed, Mr. Hughes is of opinion that some of the clays which have furnished these reptilian remains must be higher in position than the bands of limestone at Kota."

The physical conditions under which the rocks were laid down are also thus treated of by the same author:—

Physical conditions indicated by the fauna.

"One other point that requires a few words of notice and is of some interest is the probable conditions of the area, when the animals lived, of which the remains are preserved in the Kota-Maleri group. The opinion generally accepted, I believe, by all the members of the Geological Survey of India is the same as was advocated in the notes on the Pánchet vertebrate fossils,—that, with the exception of some beds on the east coast and in Cutch, the greater portion, if not the whole, of the Gondwána system of rocks was accumulated in a great river valley or series of river valleys. It would follow that the remains found are probably those of terrestrial or fresh-water organisms. The living species of *Ceratodus* are found in rivers, *Hatteria*, the nearest existing relative of *Hyperodapedon*, is a terrestrial reptile, and *Parasuchian* crocodiles, like their modern repesentatives, may very well have been fluviatile."

The type outcrop.

The Kota Group.—This set of rocks is named after the small village of Kota, on the left bank of the Pránhita, some five miles north of Sironcha, not far from which,

below the high alluvial bank of the river, there is a small outcrop of limestones in which fish remains were found, I believe originally, by Dr. W. Walker, of the Madras Army, in 1841. This gentleman carried out a boring on the chance of finding coal, and made reports[1] on the field.

Palæontology.

The fossils so found are all of ganoid fish some of which are very perfect, but the commonest remains are matted masses of smooth glossy scales. Dr. Walker supposed these remains might be of carboniferous age, and this supposition was intensified probably by his also having found traces of coaly shales; but when the specimens were examined by Dr. Falconer he recognised at once that these were fish scales, &c., and not *Lepidodendron* scales as had been supposed, and that they belonged to *Lepidotus* and *Dapedius*.[2] On being sent to England they were examined by Sir Philip de Malpas Grey Egerton, who in the same year communicated the results to the Geological Society of London,[3] and demonstrated, as far as palæontological evidence avails, that the age of the deposit was oolitic. In 1878 the volumes of our Palæontologia Indica were distinguished by a complete memoir on these fish remains by this great ichthyologist, from which we learn that the full series of fossils then laid before him embraces the following genera and species:—

Fauna.

Lepidotus deccanensis, Egerton.
„ *longiceps*, „
„ *breviceps*, „
„ *pachylepis*, „
„ *calcaratus*, „
Tetragonolepis oldhami, Egerton.
„ *analis*, „
„ *rugosus*, „
Dapedius egertoni, Sykes.

These fish are all affined by Sir Philip Egerton to liassic species.

[1] Madras Journ. Lit. and Sci., Vol. XVII, p. 261, *et seq.*; Journ., As. Soc., Bengal, Vol. X, p. 841, *et seq.*

[2] Report on specimens of bituminous shales transmitted along with Dr. Walker's Report, by Dr. Falconer, A. M., M. D., Superintendent, Hon'ble Co.'s Botanical Garden, Calcutta. Madras Journal, Lit. and Sci., Vol. XVII.

[3] Quart. Journ., Geol. Soc., London, Vol. VII, p. 272, 1851.

The only other remains associated with the fish are an *Estheria* and a *Candona*, which have been described[1] by Prof. T. Rupert Jones.

Flora.

In addition to these, but unassociated with the fish, and not in any limestone band, the following vegetable remains were found at different parts of the field :—

FILICES.

Tæniopteris (Angiopteridium), sp.

CYCADIACÆ.

Pterophyllum acutifolium.
Cycadites, sp., fragmentary.

CONIFERÆ.

Palissya jabalpurensis.
„ *conferta.*
Chirolepis, sp.
Auracarites cutchensis.

Unsettled horizon.

The horizon of these plant remains in the Kotas is still rather doubtful; but *Palissya conferta* and *Chirolepis münsteri* are from a locally bottom bed of the group, which to all appearance, in another part of the field, runs between limestones containing remains of *lepidotus*, &c., while the rest of the plants are from beds which are lower in the group than the fish beds, but distinctly above the red clay or Maleri group.

Dr. Feistmantel's opinion as to its age.

Dr. Feistmantel, the Palæontologist of the Survey, refers to this flora in several places throughout his elaborate history[2] of the Fossil Flora of the Gondwána system, according as they have been found from time to time in their different localities; and, on the whole, he decides that it is partly of Rájmahál and partly of Jabalpur age, that of Anáram being of the first, while the plants of the other localities are considered to constitute a mixed flora, and to hold a somewhat higher place in the upper Gondwána series than the Rájmahál group.

[1] Quart. Journ. Geol. Soc., London, 1863, Vol. XIX, p. 149, and Memoir, Fossil Estheriæ, pp. 81 and 127.

[2] Pal. Indica, Ser. II, 3 and 4, Vol. I.

The plants of the Jángaom valley were found by Messrs. Hughes and Fedden near Naogaom, and Chirakunt or Chárakota of map, and between Mohár and Balánpur, while Hughes and I came on the other plants in the beds at Anáram in the south-east part of the field, on the right bank of the Pránhita, about five miles north-north-west of Sironcha, which I can as yet only consider higher in the group than those of the Jángaom valley.

Lithology.

The Kota group is eminently a sandstone series with subordinate red clay bands, but characterised by the presence in it of three very strong zones of limestone; thus differing essentially from the Maleri group, which may be as shortly described as a clay series with subordinate bands of sandstone. There is certainly a calcareous element in both, but that of the lower is very poor and it decreases as the series is traced upwards. The limestone zones shade rapidly downwards into the intermediate sandstones by calcareous sands and clays; and in the zones themselves there are thin seams of bright red clays, or even carbonaceous shales in one case.

The limestones are usually grey, compact, hard splintery rocks, rather argillaceous and earthy, often seamed with white chert, in tolerably thick beds, and associated with these purer beds are other coarse flaggy and shaly beds. In one zone there are seams of tough leathery carbonaceous and bituminous shales, parts of which are at times rather coaly. The sandstones, again, are like the upper beds of the upper portion of the Kámthis, and are, in fact, often hardly to be distinguished from the clayey fragmental and banded rocks of Sironcha.

Hughes writes[1] of the lithology of this group thus:—"The higher portion of the Kota-Maleri group is not so characterised by clays as the lower. It is chiefly made up of sandstones, the most typical of which are coarse and loosely compacted sandstones, of various colors, with broken runs of buff and pink shale fragments through them, rusty-brown and grey sandstones, containing pebbles, and yellowish-grey sandstones, varying in texture, with dark stains of peroxide of iron

[1] Rec. Geol. Surv. of India, Vol. XI, p. 26

Kurnavala
Chennur
Tiruv
Virasvala Hill
Kullur
Kunnigiri
Kurvagudem
Garibpet
Kurkonda
Yedla Veg
Chundragúnd
Nacharavam
Mallampad
Gollapalle
Tharapalli
Mallampad
Anamalanka
80° 30'
2 5'
0 0'

and sub-angular pieces of yellow opaque quartz scattered through the rocks.

"Sandstones containing shale fragments are met with at various horizons, but they are of most common occurrence above the main body of clays."

Separation from the Maleris not clear.

In the middle of the field there does not appear to be any strong separation between the two groups; merely a regular passage from the red-clay series of Maleri, &c., by sandstones, not calcareous, and more red clays up to a different and peculiar calcareous band of sandstones running with ordinary variegated sandstones, over which come red clays with the thick band of limestone, the whole series of Maleris and Kotas being about 3,000 feet thick.

A change at the Gungapur sandstones.

In the most perfect section, already treated of in part in the description of the Maleri group (namely, in the traverse north-eastward from Nambála by Daramál to Itála), the highest band of calcareous rubbly grits in these Maleris forms the low ridge on which Daramál is situated, and above them come further red clays, which are succeeded, not by calcareous grits, but by a considerable thickness of ferruginous sandstones, with intercalated red clays, and a peculiar calcareous grit, over which comes a set of white and buff sands. All these beds above the top calcareous grit form the high ground between Gungapur and the Jángaom river, and they show all about Wájri, Aksapur, and Naogaom. These Gungapur beds are then succeeded by red clays and limestones of the Itála high ground.

The fossiliferous beds of the Jángaom valley in this set.

It was in these Gungapur beds, or rather in their extension westwards between Mohár and Balánpur, that Fedden found *Palissya conferta*; at the samet ime noticing a generally jurassic likeness in the rocks. He noted them as "consisting of fine softish sandstones, in parts silty, and with ferruginous bands and layers, the latter having plant-like flutings and hollow wood-like casts, so characteristic of some of the upper jurassic beds of Cutch. Moreover, some of the ferruginous

bands have septaria-like intersections. The few specimens of *Palissya* and isolated leaflets that were found occurred in the fine silty sandstones." Hughes found *Chirolepis münsteri* in the same neighbourhood.

The next fossil locality on this side of the country is at Chirakúnt, four miles south of Jángaom, and here Hughes found *Tæniopteris*, sp., *Ptilophyllum acutifolium*, *Cycadites*, sp., *Palissya* comp. *conferta* and *Palissya*, sp., in beds of the same Gungapur sub-division. Nearer to Naogaom, however, and thus coming nearer the Nambála traverse, he also found *Palissya jabulpurensis* and *Auracarites kachensis*.

At the western end of the valley, again, near Balánpur, there is a small thickness of rocks described by Hughes, in which he found irregular strings of coal in clay shales overlaid by yellow soft sandstones, obliquely laminated at the top and containing fragmentary carbonaceous markings which he is, however, inclined to look on as belonging to a higher series, the Chikiálas, next to be described. For my part, I hardly think this correlation can be carried out, for they are only partially like the Chikiálas, and I do not know of a single instance of carbonaceous traces in their typical area. These rocks of Balánpur would appear to answer rather to the sandstones with carbonaceous shale observed by Fedden near Aksapur, which are overlying the plant beds of Naogaom in regular order.

So far, all that is gained in this discussion is that the sandstones of Balánpur, Chirakúnt, Naogaom, Aksapur and Gungapur overlie the red-clay or Maléri group in regular succession, while they contain plant remains of Rájmahál and Jabalpur age.

Red clays overlapped by higher beds of this group in the Wardha valley.

If, however, the river is followed further down, an outcrop of sandstones with red clays appears at Andeli, apparently rising out rather suddenly from under high beds in the Gungapur sub-division, which certainly simulates the more typical red clay series. Then, going northward, but after a blank, there is an unmistakeable outcrop of the Maleris striking past Sirpur to the Wardha river: it is, however, succeeded, not by Gungapur sandstones, but by a higher

band of the Kota group, which has overlapped the Gungapur beds and the limestones of Itála, and which I shall refer to again as the Bebra or Sarwai sandstone band.

To the south, red clays overlapped by Gungapur beds at Isnai.

Returning, however, to the Gungapur outcrop, these beds, with their band of peculiar calcareous sandstone, trend to the south-eastward and are continued with tolerable distinctness all round past Itála, Rajáram, Sardapur, Bamena, and Kondampeta, until, at Isnai, they lap over the red clays of the Maleri group on to the Kámthis of Linganapeta. Beyond this, in the Pránhita and Godávari, though the Kota group is continued in great force, there is no further outcrop of a typically red clay group like that of the Maleri field: it is either entirely overlapped, or it is hidden by faulting. There is just one exception to this general absence of what may be considered a red-clay series, away down south of the Pángadi Vágu, in the presence of a large outcrop of red and green clays which I suppose to have been left by faulting among the Kámthis north of Bundalla, and to which I have already referred; but this is, comparatively speaking, of such small extent as not to affect the main question of the relations of the group.

Separation, evidenced by overlap, different lithology, and different life.

This is practically all that can be said of the separation between the two groups stratigraphically; that is, that the Kota group, or the limestone banded set of sandstones with subordinate clays, overlaps the Maleri group, by its lowest or Gungapur sandstones at Isnai in the south-eastern part of the field, and by higher strata in the northern region between the Jángaom and Wardha rivers. In addition to this, there is a strong lithological difference between the two. Lastly, each has a fauna peculiarly its own; the one having triassic affinities, while the other possesses remains of presumably liassic animals and a flora exhibiting characteristic Rájmahál and Jabalpur species.

I have, besides, been led to look on the latter as commencing with the Gungapurs, even though there be so many seams of red clay in that set of rocks as well as up into the limestone series, because they mark, as it

were, the renewal, and more decided existence, of circumstances under which calcareous beds were formed over different areas of the field. There was, no doubt, a strong tendency towards the deposition of calcareous matter in the Maleris, and more particularly towards the north-western part of the basin; but this ceased or slowed down in the southern portion. Then, after an interval, during which, however, no apparent strong movement or denudation took place, certain decided changes in the physical character of the adjacent country and its drainage were brought about which allowed of a thick alternating series of more arenaceous and decidedly calcareous rocks being laid down, the later members of which overlapped the red clay series at each end of the basin.

The limestone zones.

As already stated, the most definite and recognisable strata are the limestone bands, even commencing with the lowest dark-grey sandy band in the Gungapur sub-division, above which are certainly three zones without any decided arenaceous element in their constitution, which may be called respectively the Metapali, Kota, and Bágaráni zones. Of these, the Kota band is the most noted from the fish remains contained in it, though similar fossils have also been obtained from the lower one of Metapali.

First of all, and lowest, there is the calcareous sandstone band, consisting of black-weathering thick-bedded and smooth-surfaced strata, altogether at first sight remarkably like beds of rather granular limestone. The rock is, however, only very slightly calcareous, consisting of sharp and angular little particles of glassy quartz in a clayey calcareous cement, and it is of a dirty greenish-brown color internally. The band is of good thickness, 20 to 40 feet, for long distances, and then again it is only represented in thin seams with intercalated variegated sands, as it is followed southward towards Nakalapali. Thence it is traceable through a forest-covered tract to Kondampeta, beyond which a wide belt of superficial deposits covers up all rocks but a few outcrops of sandstone.

At Itála.

Higher up in the series, perhaps 200 feet from the bottom, comes a thin band of hard limestone beds associated with red clays, which only shows for any length of

outcrop at or near Itála. This is probably only a commencement of the more decided bands; for, after a short thickness of superincumbent red and green clays, there is then the thicker zone of Itála itself, which shows in and around the village in several broken outcrops of horizontal beds, in some of which a few *Lepidotus* scales were found. This Itála outcrop is unfortunately quite an isolated one owing to the wide spread of recent deposits in this part of the Jángaom valley. The beds are generally lying so flat, or are in such a troubled condition owing to the washing out of the subjacent clays, that it is difficult also to get any fair idea of their thickness. We were inclined to consider that this might be a northerly extension of the Kota band; but the general lie and strike of that band are against this, and it really answers best to the Metapáli outcrop which is striking very clearly up in this direction from the south. Indeed, if the lower sandy zone be followed out in its course, it will be found that there is very much the same breadth of outcrop between it and the Itála and Metapali outcrops.

The Metapali zone.

At any rate, at about 300 feet up in the group and along a line extending from Itála, south-east by Timapur Hatu Metapali Suraram and Busnai, there is, for the greater part of the way, a fair outcrop of limestone beds, which at Metapali itself is about a mile in width, the dip here being very low. Now and then the dip is higher, and very often the whole breadth of outcrop is not seen; but I scarcely think there can be more than 100 feet of these beds. Five or six miles beyond Busnai, it thins out, or else becomes covered up by the alluvium and gravels of the Yedlabundum stream.[1]

[1] These limestone outcrops are often to be found and followed more by the decided belts of teak trees which seem to flourish more particularly on them. The most of the country is covered by fairly large, but rather dry, tree jungle, among which the teak grows indiscriminately, though I found after a time that it is also confined to belts, and that these run with the limestone outcrops, or along the breaks in them caused by the covering sands, clays and gravels. Of course, there are other parts of the country, as down on the alluvial flats alongside the large rivers, where belts of teak trees are frequent, but these are irregular or not so defined as those in the tract between the Jángaom river and Sironcha, though even here the prevalence of the trees was accompanied by a more calcareous constitution of the alluvial deposits than is usual in other parts.

The Metapali zone is overlaid by a thick band of sandstones and clays, which must be from 800 to 900 feet in thickness, softish friable coarse-grained and light colored beds, much banded with, and full of fragments of buff lilac and pink clays with, however, frequent hard brown pebbly and conglomeratic beds. Then comes the Kota zone of limestone, which is the most conspicuous and continuous of the three in this the Pránhita area. It runs from the Jángaom river near Parwatipet, parallel to the Metapali zone, past the villages of Yemlapali, Kátanapali,[1] and Rácherla on towards Pulgaom on the right bank of the Pránhita, a few miles above Kota where it is hid under the river deposits.

The Kota zone.

There is a very poor outcrop at Kota, just a craggy ledge of hard splintery limestone beds hading up to the southwards from under the river bank; in fact, an isolated mass of tumbled beds, surrounded by alluvium or sand, altogether about fifteen feet in thickness. The dip is about 10° to north-east. The outcrop shows, uppermost:—

The type outcrop.

	Feet	In.
A laminated or platy bed made up of clayey and limestone seams and thin bands of grey fibrous magnesium limestone, with *Estheria*	1	6
Thick-bedded, somewhat nodular, laminated clayey and earthy limestones. Sometimes a breccia. Traces of fish scales ...	3	6
Thin laminated clayey and calcareous beds	2	0
Thick-bedded hard massive splintery grey and fawn-colored argillaceous limestone; sometimes a breccia or a conglomerate. Fish and fish scales	7	0
Total feet ...	14	0

No rocks are seen anywhere in the river bed so that we know nothing in this way of what is underneath; but the next lowest outcrop of rock is on the right bank of the river at Anáram, where are gravelly and pebbly sandstones with clay and shale bands having the same lie.

[1] Erroneously printed as Kolanapali in the map.

Dr. Walker's boring.

Dr. Walker's boring, made in 1841, disclosed the following succession :—

	Feet	In.
Alluvium	... 20	0
Argillaceous limestones	... 2	6
Blue clay	... 1	0
Argillaceous limestones and shales	... 6	4
Shale and slate coal	... 2	6
Limestone	... 1	6
Coal and shale	... 0	9
Limestone (not pierced)	... 0	6
	35	1

Practically, this is merely a section of what is exposed in the river outcrop except that it shows two thin seams of carbonaceous shales, which have no doubt been washed out of the exposed outcrop.

In time, Mr. Philip Wall visited the river area now under description and put a boring down at Kota, which tells us more of the strata underneath the place. The following extracts are taken from his report :—

Mr. Wall's boring.

"On my arrival at Kota I found I was still in the same series of sedimentary rocks I had been passing over in my journey along the river, and was fortunately soon able to identify the limestone at Kota under which the coal was presumed to exist, with the limestones I had observed at other places on the river, one of which was at a point 80 miles lower down.

"This limestone, although seen cropping out at several places on the river at Yeytoor, a village two miles below Chintagorem, at a point on the left bank opposite Pallemella (Warrugoora), and subsequently, as I discovered, at a place a little north of Kumalapetta, I had not been able to observe beyond a very small extent in thickness. I, therefore, proceeded on arriving at Kota to carry out my original intention to start my people to bore, and immediately selected a site upon this limestone which offered the best facility for carrying on the work.

"At Kota the beds of limestone dip at a very low angle and a very small amount in thickness of the beds can be observed;—resting immediately upon them is alluvial soil, forming the river bank at this place for some distance both up and down the stream. The nearest place where beds lying beneath those at Kota is to be seen is at Annaveram, one mile distant; here a whitish sandstone crops out, having also a north-east dip. By comparing the inclination of the strata at Kota and the distance between these two places I found the thickness of the intervening beds did not exceed much if at all 200 feet. Having started my boring, therefore, at Kota, I determined to continue it there and examine as much as possible of these concealed strata, which I could nowhere, either up or down the river, examine sufficiently in detail at the surface.

Apparently touches the Anáram beds.

"The boring was commenced on the 19th of March; on the 6th of May it had reached 111 feet in depth and came upon a bed of red sandstone. This proved about five feet in thickness, and was succeeded by blue clay and sandstone alternately; we continued the boring until the 14th, when it had reached the depth of 145' 8" and was in a white sandstone much resembling that I had seen cropping out at Annaveram, and which I concluded to be the same.

"The boring was through thirty feet of very hard limestone beds with partings of thin beds of shaly and fibrous limestone and clays, after which a series of hard calcareous clays and marls, variegated in color, or of decided blue or red, until the sandstone was reached; nowhere did I perceive the slightest trace of coal.

The limestone band appears to be thirty feet thick.

"Through the limestones and succeeding clays our tools brought up frequently traces of the fish remains mentioned below.

"I was somewhat surprised I did not pass through in boring the bituminous shale alluded to by Dr. Walker in his report. Upon examination of the beds in position above those I was boring through, however, I found this substance interstratified with thin layers of sandstone, about one inch thick, and layers of limestone, and at the same time quantities of the fish remains.

"At Kota in the limestone beds I found great abundance of fish scales, no doubt similar to those brought from this spot by Drs. Walker and Bell; they proved of much value to me as identifying the beds at Yeytoor, where I also found them, with those at Kota.

Organic remains.

"At Yeytoor I also found impressions, answering the description given of the Crocodilian remains found by Dr. Bell.

"In the bed of the river in several places I found masses of lignite; it is of a jet black color, and from its frequent occurrence has no doubt been instrumental in giving the reputation to the Godávari river as being a coal-producing district. It does not appear to exist in beds but in isolated masses in the alluvium from which it is washed out by the action of the river.

Carbonaceous shales.

"One piece was enclosed in the sandy bed of the river, surrounded by heaps of large water-worn pebbles, with which it could never have been transported on account of its extreme friability; the central portion is silicified and preserves apparently the structure of the original wood from which it has been converted; the outer coating is the lignite in various states of carbonisation, part being brown and preserving the original texture of the wood and still even flexible, while other portions are completely converted to a substance having all the appearance of coal. The silicified nucleus is traversed by veins of iron pyrites."[1]

About three miles further down, but out in the wide sandy bed of the river, I, too, found a mass of rather coaly carbonaceous shale striking out of the sand at an angle corresponding with the proper dip and lie; but I fancy it can hardly be *in situ*. Another carbonaceous and shaly outcrop may be seen many miles further down in the Godávari, a short distance west of the Indrávati junction, in the right bank, north of Boraigúdem.

The immediately overlying beds of the Kota outcrop are not known, though there is not much of a blank between this and the next outcrop, perhaps 150 paces, further

In other parts the zone is thicker.

[1] Madras Journ. Lit. and Sci., Vol. XVIII, pp. 259-264.

up the river, where there is a series of red, yellow, and dark-grey clays associated with soft sandstones. I think myself that the band of the limestones is generally much thicker than Mr. Wall's boring gives it, and possibly there may be some higher beds hidden in this blank.

The next best outcrops of this band of limestone are seen further to the northward at Kátanapali, which place is on a decided but low ridge of a portion of the outcrop which is here, owing to the low dip, of considerable width. I calculated, from a better outcrop, about a mile or so more to the north, that the thickness of the zone at this part must be at least 87 feet. Fish scales are numerous in the flat surfaces of hard and thick splintery beds in the nala east of the village.

Southern extensions of zone.

South-eastward from Kota, the continuity of this outcrop appears to be broken, perhaps at the cross-fault in the Arjungúta hill station; at any rate, the next band of limestones seen in that direction crops up to the south-east of Sironcha, at Tondála and Nandigaom, shifted slightly to the westward of the proper run. This outcrop is very close to the Sironcha sandstones, and apparently succeeds them in proper order, since there is hardly any room for the Kota strata below the limestone zone to have thinned out and run in here between the two. There must, in fact, be a faulted line along here by which this higher outcrop of the group is let down against the Kámthis of Sironcha. The outcrop is continued nearly to the Indrávati bend of the Godávari, and is then cut off by the Mádapur cross-faults, to the south of which the group has a much wider outcrop and shows traces of the thin limestone zones at Ardium Ankisa, and yet more eastward near Aserali. To the south of this tract rather wider but short outcrops, indicative of two bands, show in the river bank at Boraigúdem, and in the Pankena tributary, the higher of which, at the first village, has yielded some fine specimens of fish, one of which shows the skeleton. These southern outcrops are, however, much obscured by the river deposits and they eventually become covered up in the thick spread of clays and gravels of the watershed between this

Faulted boundary, and breaks in continuity.

river and the Pángadi Vágu. This group, as represented by its sandstones, is very fairly seen all the way down to the latter river.

The overlying sandstone band overlaps red clays.

In the Pránhita field, the Kota zone is then succeeded by a very strong and thick band of soft sandstones with frequent red-clay bands, the lower portion of which is a very bright-colored series and well shown in the low river cliffs between Kátanapali and Enchapali. Above these are harder ferruginous pebbly and conglomeratic sandstones which make up the ridge east of Kota fort. The band thickens out a good deal at the Jángaom river and then strikes away northwards in the strong and rather high scarped ridge of Serwai at the end of which near the Ankona hill station, the beds are found to have overlapped the lower zones of limestone and sandstone and rest directly on the red-clays of the Maleri group in its outcrop near Sirpur.

The Bágaráni zone.

The third or Bágaráni zone comes next, but it does not give a very continuous outcrop for any long distance, except between Dagaom and the Metapali tributary of the Jángaom river. Outcrops of what appear to be the same band occur near Somtum on the Pránhita and again at Asarali on the Godávari above the Indrávati mouth. Above this again come more sandstones of the usual kind for a good thickness.

The position of the Anáram sandstones in the group.

The sandstones of Anáram on the right bank of the Pránhita have already been mentioned as being stratigraphically lower in the series than the Kota limestone zone, and in fact they are shown to be so by Mr. Wall's boring. If then the strike of the beds to the northward be at all regular, these beds in which we found the Rájmáhal plants, *Palissya conferta* and *Chirolepis münsteri*, should be part and parcel of the sandstone zone lying between the Kota and Metapali zones of limestone; and this is what I should preferably consider as their position in the group. Still, the Anáram beds are locally bottom beds of the group at this point; while there is really so much covering up of the strata by the Yedlabundum stream that it is absolutely impossible to say whether

they do run right on, in this normal strike, between the limestone zones, or that they may not be really lower beds of the group which has just curved round here from Kondampeta. In this last position, they would be of the Gungapur beds in which also the plant remains of the Jángaom valley occur.

Lithology.

The sandstones of Anáram are reddish brown-weathering or yellowish red harsh rocks with frequent seams of quartz pebbles and lumps of pink and lilac clay, or seams of these clays, which are often on the surface much hardened and porcelainised through exposure. Here and there, and very rarely, in these shales are patches of fragmental vegetable remains, in which also are small twigs and sprays of the *Palissya* and *Chirolepis*. The best fossils are found in some loose fragments of rock which had been used for the foundations of the old fort of this place; but others were found in a ridge outcrop which rises up on the right side of the road from Anáram to Sironcha, about a mile from the latter place, where there are some old quarries. It is rather a high lying outcrop of red and lilac, or brown purple, laminated sandy shales and pale lilac shales, many of which are much indurated. They are also at times rather pebbly. The sandy laminated lilac and brown purple shales do not appear to contain any fossils, neither do the very compact splintery lilac beds; but the more earthy and fine sandy shales of a pale lilac color contain many patches of the fragmental stems, among which are tufts of the *Palissya*.

Doubtfully of the Upper Gondwána series.

Chikiála group.—I place this group very doubtfully as a member the Upper Gondwána series. At first, on arriving in the region with the features of the different groups of the same series occurring in the coastal region of the Godávari still fresh in my mind, I was very much struck with the remarkable lithological resemblance to the Tripati sandstones which, by the way, are also well separated by overlap from the underlying Rágavapuram shales to an extent almost amounting to unconformity. Here, however, I think, these sandstones are really unconformable on the

Kotas; while in their lithology they are also similar to other and younger groups of sandstone strata in Central India.

In the Enélai plateau and Chikiála scarps.

Some eight or ten miles to the north-east of Sironcha, there is a clearly defined, though low, steep-sided and flat-topped range of hills, about 200 feet high, composed of sandstones which are dipping slightly to the north-east. The same series is continued north-west by broken hills into the higher scarped range overlooking the village of Chikiála on the left bank of the Pránhita, and, as we first met these rocks here, we have called the group after that village.

No fossils.

No fossil-remains of any kind have been found in the group.

Extent.

Altogether, as will be seen in the map, these rocks form a belt of about eight miles or less in width, lying on and parallel to the other groups of the series, and about sixty-eight miles in length from Rebni in the Wardha basin to the reach of the Godávari below Enchapali. In the Pránhita region they form low plateau hills, as that of Enélai near Sironcha, or less regular hills with western headlands and low scarps; but southwards from that town, they constitute lower and lower ridges bordering the more decided eastern ranges of transition quartzites and shales.

General facies.

The rocks are always of pretty much the same kind, light brown red yellow and buff sandstones and heavy conglomerates which are at times extremely ferruginous in their constitution. There are, as far as I know, none of the strong clay bands, or seams of clay and shale fragments so characteristic of the Kota group.

Contact with the Kotas not seen.

They are unfortunately covered on the western edge by such a strong talus of recent gravels and clays that I have been unable to find any case of junction between them and the Kotas, but they do certainly appear to overlie different members of this group. At the same time, there is such a manifest different lie of the beds from what is generally seen of the other groups of the

Gondwána series, as exhibited in the Enélai plateau especially, that this appearance of unconformity receives thereby a further amount of probability. All over the Gondwána area the rocks are denuded in ridges and valleys, the former being always with the strike of the beds and having steep scarps and long dip-slopes; but here, suddenly as it were, there is, to the north of Sironcha, a new arrangement of hill scenery, which is due in a great part to the flatter lie of the beds, and which in its strangeness strikes one at once as indicative of a more decided change in the stratigraphy than what might be caused by a mere roll up of the hitherto higher dipping beds at a lower angle.

Apparent unconformity, by lie and character of hill scenery.

Another feature in these ranges north of Sironcha is the occurrence at their basal outcrops of springs of water which appear to flow all the year round. At certain points all round the base of the Enélai plateau, while all the rest of the country is dried up, as at Sirkonda on the east side and again at the heads of the small bay-like valleys on the western side, there are such streams. Further to the north too, away in the wilder reaches of the Pránhita valley about Darsiara, springs of fresh clear and cool water are found flowing from basal outcrops. I could only account for these being all at much the same horizon and so unevenly distributed by supposing that they are outlets of water gathered on these hills which has settled down in them and found a freer egress on a denuded and fairly level plane of the subjacent Kota rocks.

Springs of water near basal outcrops.

In point of fact, all the evidence goes to show that we have here a series of sandstones which must be unconformable on the Kotas, but it is not clear whether these should be considered as belonging to another formation; and in this condition of uncertainty I have thought it better to leave them as doubtfully belonging to the Gondwánas.

A distinctive lithological feature of the group is that the beds are often extremely conglomeratic with a very coarse shingle of white quartz; while they are also more ferruginous than either of the other groups, and even, locally, more so

Distinctive lithological characters.

than the Kámthis. It is, in fact, the iron-producing group of the Prán-hita-Godávari valley, and thus ranks next to the Barákar group in economic value.

Style of the rocks in the Chikiála scarps.

Chikiála itself is on Kota sandstones; but very soon after leaving the village to ascend the ghât leading up to the lofty plateau, the path is found to wind among débris of ferruginous sandstones and conglomerates which are altogether very different looking to any of the rocks found in the plains. A good deal of the lower half of the slope is made up of coarse sands and conglomerates. Near the top of the scarp, or say fifty feet down, there are thick beds of a friable, coarse-grained, red and yellow sandstone, which near the top are overlaid by highly ferruginous sandstones and pebble beds, with a strong band of concretionary clay iron-stone with large ellipsoidal concretions. Above this band are hard, thick-bedded, and again flaggy silicious iron-stones or very ferruginous grits, rather vitreous; and next comes a thin set of scabrous, irregularly laminated, ferruginous sands and clay-stones, with heavy, coarse, hard, purple and red sands and pebble beds forming about twenty feet of the capping or upper surface of the plateau. These are all wonderfully like the beds of the Tripati group in the lower Godávari district.

Like the Tripati sandstones of lower Godávari district.

Style of rocks in the Enélai plateau.

The Enélai plateau is a very typical area of these beds. On the eastern or Sirkonda side, the edge cliffs show from the base about eighty feet of exceedingly coarse gravelly sandstones, ferruginous, having a dip of 5° to 10° westward. From the edge of the steeper scarp one passes up over higher and higher beds of pebbly, ferruginous, yellow red and brown sandstones, the beds of the upper part of the plateau being at times good even-grained softish sandstones with flaggy seams of more ferruginous constitution. The scarp beds are full of pebbles of white quartz and various quartzites with a few sub-angular and rounded pieces of grey black and blue slate or clay-slate. The white pebbles are exceedingly common.

On the plateau, the more sandy beds are seamed generally across the bedding with iron infiltrations, while they are often themselves extremely ferruginous the weathered surfaces being of a black-blue color, though internally the rock is seamed with bright metallic iron-ore. In fact, the cement or matrix of some of these sandstones is simply metallic grey oxide of iron. Softer purple and variegated clayey sandstones occur with the upper beds.

From an examination of the western side of this plateau, it would appear that there are two, if not three, bands of very ferruginous sandstones and white quartz pebble beds; but the ferruginous constitution is more particularly developed or displayed at certain outcrops and points of exposure, as exceedingly coarse harsh rugged dark-brown and purple-black beds, occasionally very cindery-looking or scabrous, and mostly weathered in rough nodular and mammillary surfaces of exposure. Bedding and lamination are much obscured and even obliterated by subsequent ferruginous cementation and infiltration, and this has given a banded or laminated appearance often almost at right angles or oblique to the real stratification. With these more ferruginous bands of coarse sands and gravel beds are seams of yellow and red hardened clay and sandy clay with filled-in cracks. At the highest point, east of Gáka-peta, there is a third or uppermost ferruginous band, and it is capped by a seam of clay-iron-stone concretions like the uppermost beds of the Chikiála scarp.

The northern outcrops on the Jángaom river.

Near the northern end of the outcrop, or belt, of these sandstones, north of the Jángaom river near Kundapali, the hill station there is an outlier of the plateau range of hills and is made up of undoubted Chikiála. The country at the base is strewn with pebbles and shingle of white quartz, quartzite, black and white cherts, clay-slates, and great lumps of heavy dark-brown ferruginous conglomerate. The hill station is capped with this hard and heavy ferruginous conglomerate. All up the hill one passes over the edges of horizontal beds of coarse red and grey clayey sandstones and gravelly beds with seams of big pebbles and shingle.

And thus throughout the field the characters of coarse ferruginous sandstones, and gravelly and shingly beds, with frequent seams of white quartz-pebbles, and bands of more strongly ferruginous strata, lying nearly flat, or with a low dip to the east-north-east, and giving generally low plateau ranges of hills, or scarped headlands, are preserved in all their entirety. They may be likened locally to many other sandstone bands in the whole Gondwána series, as the Tripati sands in the Godávari district, or even some portions of the Kámthis in this very area; but there is no doubt of their being a distinctly recognisable series in the field, and that they occupy the area laid down.

The southern outcrops.

At the southern extremity of the field the outcrop, after narrowing for some time, again widens out around or below the Enchapali hills, and here we have again the unmistakeable flat-lying harsh variegated sandstones, with their pebbly gravelly and ferruginous beds. They also give the clear flowing springs at several points at their base or junction with the underlying Kota beds.

Character of the eastern boundary.

The junction of this highest member of the sandstone series with the transition and lower Vindhyans is obscure; but I think myself, though their eastern boundary against these rocks is a wonderfully straight one for so many miles, that they are really, after all, lying naturally against a tolerably straightly denuded edge of these rocks, rather than that they are faulted against them. At one or two points, however, there is evidence of crushing, or of faulting, as near Mutlagúdem at the mouth of the Jángaom river, and again near Sirkonda; only I am not so sure that this faulting and crushing are not in the transition and lower Vindhyan rocks themselves, while the running of the boundary of the Chikiálas with these lines of fracture is merely a coincidence. In the few other localities where I have seen the junction, the boundary is a natural one, that is, the horizontal beds of the Chikiálas are abutting against the denuded face of transitions, or Sullavais, as the case may be. Again, towards the Indrávati bend of the Godávari, wherever I could get a close enough boundary, the strata are baying into the indentations between the hill

spurs, while at Asarali and the river itself, and so on by the Enchapali outcrop, the lie of the strata is always easy.

The fact is, the map on so small a scale as that now given, or even on the 4 miles to the inch scale on which our detailed work is laid down, gives a deceptive idea of straightness to the boundary line, as it were, of a faulted line; but on the larger scale it is not so straight, or only as straight as a long scarped or steeply denuded valley side, or coast line, would give, more especially if that line were along a system of old dislocations in the strata, as is the case here.

CHAPTER IX.—LATER FORMATIONS.

Lower Deccan Traps.—A small portion of the eastern edge of the main area of this series just touches on the north-western edge of this field, and outside of these are a few small outliers all of which need very little notice in the present paper. The patch of the main area has its trap flows lying on Kadapah rocks and all the groups of the Gondwána formation except the Tálchirs and the Chikiálas; while the outliers rest on Kadapahs Kámthis Maleri beds or Kotas, so that the absolute separation of the series from the Gondwánas is quite clear.

Eastern edge of the great Deccan area.

I have only myself seen these beds in the small outlier which caps the Ankora hill station near Sirpur in the Wardha valley; and here they are, as I believe they are also in the other patches, simply massive traps, some of which are full of geodes of chalcedony. All the hill slopes are much strewn with huge fragments of the generally compact and fine-grained dark-green or nearly black augitic rocks, so that it is difficult to say where they really commence to occur *in situ*. I traced the sandstones of the base for almost two-thirds of the height up the slopes; and if we take the height of the low country to be about 900 feet above the sea, this would give a capping of these rocks of about 200 feet in thickness, which appeared to me to be about the real thickness of them. There is rather a large spread of these rocks on

the top of this hill; and they are lying flat, or have a slight dip to the eastward.

Older alluvial deposits of the Godávari.—To an ordinary observer the low-lying parts of this great river basin would appear to consist of little else but superficial deposits which might be classed generally with the river alluvium; but the latter and the wide spreads of soil of different kinds, or the many sands derived from the degradation of the superabundant arenaceous rocks, are easily separable from certain more compact clays and clay gravels which are very common in this very region, and indeed all over Southern India.

Otherwise, implement gravels.

Hitherto I have written of these as implement gravels or, sometimes, as lateritic deposits, from the prevalence in them of lateritic or ferruginously cemented débris and surface accumulations, or from their frequently containing palæolithic quartzite implements. Here too, though I have not found any of these rudely chipped stone axes and scrapers *in situ*, they nevertheless do occur in such a way that they cannot but be considered as to have been washed out of these deposits. They might indeed be called fossil-wood gravels, they are so crowded with fragments of silicified trees in certain tracts.

Lithology.

These gravels consist of tolerably hard calcareous (kankary), but sometimes also ferruginous (and then lateritic), more or less sandy clays with strong seams of very coarse gravel and shingle. There is very little bedding seen; the general stratigraphic character of the deposit being such as might be exhibited by great banks of shingle fine gravel or sands and clays, accumulated irregularly over and among one another. The calcareous element is most visible in small lumps and strings of travertine or kankar sticking out on the surfaces; but it is also fairly well distributed through the clays in small particles, or it often occurs as a cement in the shingles and conglomerates. The ferruginous matter occurs as small pellets of red or brown iron-clay scattered irregularly through the clays, or gathered thickly over the surface, and also cementing the shingle; or as irregular

and discontinuous cruciform pipes; or there may be seams of these pellets. At other times, but rarely, there are superficial exposures of thick seams of iron-clay, 6 to 15 inches thick, which are practically beds of what is usually called laterite. The more ferruginous forms of these gravels occur to the west and south of the Enchapali range of hills, or on the watershed between the Pángadi Vágu and the Pankena tributary of the Godávari, and there are small lateritic tracts to the north-north-west of Sulbáka.

Great part of the gravels derived from the Chikiálas.

The amount of shingle and pebbly gravel occurring in these clays is remarkable, and my attention was more particularly drawn to them in the neighbourhood of Sironcha, in the low country below the Enélai plateau, where it is evident that the most prevalent débris must have been derived from the heavy conglomerates of the Chikiálas. Indeed, this is their constitution for nearly the whole length of their eastern edge, and for a good breadth out over the western plain.

Silicified fossil wood.

The next noticeable feature about these deposits is the enormous amount of fossil wood contained in them, and this, too, is distributed mostly on the eastern side of the country, with the white quartz-shingle,—a circumstance which made me suspect for a long time that the fragments might even have been derived from the same formation. Very close and long-continued search failed, however, to show that fossil wood does occur at all in the Chikiála sandstones.

Its mode of occurrence and extent.

The fossil wood occurs with more or less frequency over a belt of country running down the middle of the field alongside the belt of Chikiála sandstones, from near the Wardha river right down past Sironcha into the proper valley of the Godávari about Albáka, though it begins to be less common below the parallel of the second barrier at Enchapali. It is found of all sizes, from small hand specimens up to trunks of trees ten to fifteen feet long, lying on the surface, sticking out of the clays, or exposed in deep sections of the stream banks. The trunks are always devoid of branches; indeed, there are very few showing even a tendency to branch, and I only

know of one case in which there was any appearance of swelling out at the thicker end as towards a bole, or root, as is very often the case, for example, in the silicified trees of Trivucari near Pondicherry, which are exposed in the tertiary Cuddalore sandstones. Thus, though the fragments are still rather angular and apparently not much water-worn, the inference is that they have been transported some distance, or at any rate, that they are not trunks fallen *in situ* or near their places of growth.

Exogenous.

The wood is apparently all of the same kind, exogenous, and perfectly silicified; but its internal structure is not at all well displayed. The medullary rays and rings of growth are distinguishable with difficulty, and there is usually a pellicle of dull white amorphous quartz, as of an infiltration which had been deposited between the wood and the bark.

Compared with the deposits in Pegu.

These appear to be the only fossil-wood beds known among the post-tertiary deposits of the valleys of the peninsular area, the only other deposits with which they can be compared being the fossil-wood group in Pegu,[1] which is considered to be of pliocene age. Here, however, there can be little question as to the fresh-water origin of the deposits; and the age must be the same as that of the rest of the Godávari gravels which are supposably post-pliocene.

Mammalian remains are said to have been found down here, but I did not meet with any myself nor could I get any reliable record of such.

In the Wardha valley, or near Sirpur and Ankora, I found many chipped quartzite implements lying about on the surface with loose fragments of fossil-wood. Here also, and in the Jángaom valley, the gravels are largely composed of débris, which is derived from the Deccan trap series, and the limestones and shales of the Kadapah formation in the same region.

Alluvial deposits.—Both the Pránhita and the Godávari are bordered by very extensive belts of alluvium, which is often of considerable

[1] See Manual of Geology of India, 721.

resting on this coal can be fairly traced at intervals for some distance, and after running along the river for about a mile, it turns in towards the right or south-west bank. Here its course becomes obscure. Borings were put down by Mr. Vanstavern near the spot where the coal would probably crop out on the bank, but without success. Another thin seam, only 2 feet thick, has also been detected by Mr. Vanstavern on the right bank of the river. This, like the two first met with, thins out within a few yards in one direction.

I reached Dúmagúdem on the 25th December 1870, and learned from Colonel Haig that, besides the coal at Lingálá near the mouth of the Tál, some had been reported farther down the river at a village named Madaváram below Bhadráchalam. This place is below the first barrier on the Godávarí, and is consequently at all times in free communication by water with the coast, whilst Lingálá is above the first barrier, and, although communication is now possible during the greater part of the year, it is not easy for laden boats except for a few months. At the spot where coal was said to have been found, I could detect nothing except some shaly dark-coloured sandstone, but the rocks around were unmistakably Damúdás, and there was every reason to hope for success in the search.

An examination of the ground showed that the Damúdá rocks extend for a short distance on both banks of the river, but that sections are very few and imperfect. On the left bank, which belongs to the Upper Godávarí[1] districts, there are scarcely any rocks visible except at the hills near Daorpali, and these are probably of a higher group, nearly the whole surface elsewhere being covered with alluvium. The beds appear to extend about 6 miles along the river from Gogubáká to Nándigúr, but not more than from a mile to a mile and a half from the bank. On the right (south) bank of the river they extend about 5 miles from Paláram to the bend below Madávaram stretching for 1½ to 2 miles inland. Above Paláram there is a break occupied by metamorphic rocks for 1½ miles; above this, again, at Pundigúe the Damúdás re-appear and occur for about 1½ miles to a little above Amraváram, then they are covered apparently by the Kámthis, but the two groups here resemble each other so much in mineral character that their limits are difficult to define, especially as nearly the whole surface of the country is thickly covered with alluvial deposit. The Damúdas near Amraváram cannot be traced more than about 1½ miles from the river's banks,

[1] I do not know who bestowed this name on the districts, but it is an absurd misnomer. The Upper Godávarí can only be that portion of the river's course above its junction with the Pránhita, if not higher still, where it traverses the Bombay Presidency. Sironchá, at the upper extremity of these "Upper Godávarí districts," is 210 miles as the crow flies from the mouth of the river and 400 miles from its source.

beyond this limit they are entirely overlapped by the Kámthis.

Along the right (or south) bank of the Godávarí a tolerable section of the Damúdás is exposed, consisting of conglomerate, sandstone, shale and clay, but no coal. There are, however, many breaks in the section, and it is evident that an examination of these by boring would prove conclusively the presence or absence of any bed of coal extending over the whole field. Local beds, of course, might be found elsewhere, but their value must be comparatively small. It is also manifest that a thorough exploration can only be made south of the river; as to the north the beds are so much concealed that, except in a few spots, all borings must be put down at haphazard.

The general dip seen in the river's bank near Madaváram is to the westward, the rocks at the village being inclined at a high angle and much broken and disturbed; a short distance to the east down the river there is an anticlinal, at the spot where a small stream enters the river. From this point eastwards to the bend of the river, a distance of less than a quarter of a mile, the rocks either have a low dip to the east or are horizontal, and the prevalence of conglomerate shows them to be in all probability near the base or limit of the formation.

It is evident that the anticlinal exposes the lowest rocks to be seen on the river bank, and that a boring at this spot must penetrate beds lower in the series than any exposed elsewhere. On the arrival of the boring tools, I arranged with Mr. Vanstavern for a borehole to be begun at this spot. This was commenced on January 17th and carried on until April 12th, up to which time 192 feet had been penetrated; the borehole was then stopped in consequence of the tools being required to prove the coal discovered on the opposite side of the river. The section passed through was—

	Ft.	In.
1.—Brown sandstone	24	6
2.—Shale and clay of various colours, mostly dark-grey ...	21	1
3.—Coal and shale mixed	0	6
3.— Dark-grey shale	0	7
3.— Ditto ditto with fragments of coal	0	8
3.— Ditto ditto	18	9
4.—White sandstone, conglomeratic in places, with thin beds of shale towards the base	53	9
5.—Shale and clay with a little sandstone	37	2
6.—Coal	0	8
6.— Black shale and coal	1	4
7.—Dark-grey shale with a few fragments of coal in two places	26	1
8.—White sandstone	8	0
	193	5

I next arranged for a series of fourteen borings to explore the portions of the section not exposed in the river banks to the west of Madavâram between that village and Damercherla. These varied in depth from 6 to 200 feet, according to the extent of the breaks in the section, and the plan proposed was that all the smaller boreholes, not exceeding 35 feet in depth, nine in number, should be made by jumpers with extra lengths of light rods to screw on. The remaining five boreholes alone would require the use of the heavier boring rods. In the ground opposite Madavâram no boreholes were put, because the breaks in the section are trifling, and the disturbance so great that there is reason to believe that a repetition of beds takes place.

To the west of Damercherla one or two additional boreholes might have been required, but a little beyond the village the beds turn up, dipping east, and then roll over again, and just beyond the small anticlinal, very unpromising conglomerates, perhaps belonging to a higher group, come in, in which there is no break of section which could conceal a coal seam. Two or three small jumper holes were put down to the east of Madavâram.

Of the holes proposed six were carried out, *viz.*, four jumper holes and two boreholes, when peremptory orders were received from the Government of India to discontinue all boring operations in the Nizam's dominions. It is doubtful whether the boreholes in the bed of the river were in the Nizam's dominions, but pending a reference to the Government of the Central Provinces, one set of boring tools was moved across the river into British territory in order to test some ground near the boundary of the field, and close to the base of the measures, on a horizon which did not appear to have been proved by the borings on the opposite bank.

It should be stated that the borings, so far as they had been carried out on the right bank, had shown the existence of sandstones and shales similar in every respect to those seen in the bank of the river, except that in two or three instances small fragments of coal, proving the existence of very thin seams, probably not exceeding two or three inches in thickness, had been brought up by the borer. These little seams, although absolutely worthless in themselves, are of importance, as indicating that the mineral does occur in the beds, and that hopes may be entertained of larger seams being found.

The place selected for a boring on the north or British bank of the Godâvarí was on the right or west bank of a stream called the Ganár, rather less than half a mile from the Godâvarí, and about the same distance east of the village of Tátpali, at a spot where some brown sandstone, dipping to the south, is seen on the bank of the watercourse. A little more sandstone of the same kind is seen up the stream to the

north, and then metamorphics crop out, the latter appearing about 500 yards north of the spot selected for boring. For some distance east and west all is alluvium. It was hoped that a borehole at the spot selected would afford a section of the lowest Damúdá beds; lower than any passed through in the boring east of Madaváram. The borehole was commenced on the 12th April, and the section traversed was—

		Ft.	In.
(No. 1).	Soil and gravel	8	6
[1].—	Brown and yellow sandstone	25	6
2—.	Shale, pale above, darker below	7	0
	Coal	3	0
	Do. mixed with shale	1	0
	Dark carbonaceous shale	5	0
	Coal	3	0
	Dark shale with 2 inches coal	6	0
3.—	White sandstone	27	0
		86	0

The higher 3 feet of coal appears to be of better quality than the lower; an analysis of the small fragments washed from the samples brought up from the borehole gave the following (average of three samples from three different levels)—

Volatile	37·7
Carbon	42·7
Ash	19·6
	100·0

The volatile portion comprised 10·8 per cent. of water. This is by no means a good result, but still some use could be made of such coal, and it should be remembered that analyses of such samples as are obtained from borings are only approximations, although they are usually not far from the true composition.

When I heard of the discovery of coal I was about 40 miles from the spot. I marched to it at once, but, before I reached it, Mr. Heppel, who was carrying on the borings, had commenced a second borehole on some sandstone in the bed of the Ganár

[1] The numbers 1, 2, 3, before the several beds in the sections, indicate those which are supposed to be representative of the same part of the series in each.

stream below No. 1 borehole at a distance from the first 125 yards south-east-by-east. This (No. 2) gave the following remarkable section :—

			Ft.	In.
(No. 2).	1.—Yellow and brown sandstone		28	0
	2.— Shale, partly dark-grey, partly buff		1	6
	Coal		2	0
	Shale		2	2
	Coal		0	6
	Shale		0	6
	Coal		1	4
	Shale		1	4
	Coal		1	0
	Shale		1	2
	Coal		1	8
	Shale		1	2
	Coal		1	0
	Shale		0	10
	Coal		1	0
	Shale		2	8
	Coal (shaly)		1	9
	Shale		1	4
	Coal		0	8
	Black shale		5	0
	3.—White sandstone		3	2
			59	9

Altogether the combined bed of shale and coal measures 28 feet 7 inches, of which 11 feet 8 inches is coal, but the bands of coal and shale are intermixed in a way which would much increase the cost of working the seam. The astonishing change, however, in so short a distance as 125 yards from a bed 25 feet thick, containing 7 feet of coal in two well-defined seams, exceeds anything usual even in India, amongst the very variable seams sometimes met with in the Barákar group, and this amount of change within so short a distance rendered it doubtful whether the seam could be traced to any distance.

It was now desirable, 1st, to ascertain the extent of the seam, and 2nd, its quality. For the extent two boreholes were put down, one to the east, the other to the west, at a distance of about ½ mile from No. 1, on the supposed strike of the coal seam. All the ground east and west for a considerable distance being completely covered by alluvium, the true strike could only be inferred from the line of outcrop of the metamorphic rocks to the northward. To the east the borehole (No. 4) was a complete failure. It was put down in an open plain north of the village of Ganára

It passed through 34 feet of earth and 18 feet of quicksand, in which no further progress could be made, as the sand filled the tube faster than it could be removed by the "pump" or mineral lifter. A second borehole, 200 yards farther south (No. 5), was equally unsuccessful. After passing through 22 feet of soil and 24 feet of quicksand it also had to be abandoned. There was not time for more attempts in this direction.

The boring to the west (No. 3) was on higher ground, just south of the village of Tátpali. It gave—

		Ft.	In.
(No. 3).	Soil and gravel	3	7
1 ?	Sandstone, yellow, brown, and red	29	9
2 ?	Pale coloured shale	10	0
	Red and yellow sandstone with some shale	7	0
	Shale, pale and dark	13	0
3 ?	White sandstone with a little shale and brown sandstone ...	24	8
		88	0

In my absence this borehole was stopped by Mr. Heppel, and another (No. 6) started 250 yards to the south-east. This was on somewhat lower ground, and, as the beds dip south at a low angle, the section is probably that of the same beds—

		Ft.	In.
(No. 6).	Soil	11	0
1 ?	Brown sandstone	13	10
2 ?	Buff shale	6	0
	Red sandstone	2	0
	Dark shale	6	0
3 ?	White sandstone with darker bands	46	0
		84	10

These sections, I am strongly inclined to believe, are in the same beds as Nos. 1 and 2. We have the same general succession, brown and yellow sandstone above, then a thick bed of shale, and then white sandstone. I have recommended that one of the boreholes should be carried out to a greater depth on the possibility of these beds belonging to a higher horizon, but I cannot think this at all probable. The evidence afforded by these boreholes appears to indicate that the coal thins out and disappears to the westward within a short distance.

Meantime a locality for a small pit had been selected up the Ganár stream, 350 yards north-east of No. 1 borehole, at a spot where some yellow sandstone, just like that immediately over the coal, crops out in the bank of the nála, in the expectation that this would be close to the outcrop of the coal, and that a sinking of a few feet

would produce abundance of coal to enable the quality to be fairly tested. A jumper hole, subsequently deepened by boring (No. 7), was put down in order to ascertain the presence of the coal. This gave—

			Ft.	In.
(No. 7).	1.	Yellow sandstone	29	6
	2.	Buff shale	24	0
		Dark shale	6	0
		Coal	1	3
		Dark shale	26	3
			87	0

showing that the beds are nearly flat, and that a great increase of thickness in the shale has been accompanied by a diminution in the coal. A pit was, therefore, commenced close to No. 2, but when it was only 13 feet deep, the quantity of water met with retarded progress so much that it was considered advisable to commence another on the high ground 30 yards west of No. 1, as, although it would be a little deeper, it would not be equally liable to flooding, and might be used for the extraction of coal. A borehole has shown that the section is the same as at No. 1. This pit is now in progress.

Meantime one more boring (No. 8) was made only 200 yards west-by-north from No. 1. The section was—

			Ft.	In.
(No. 8).		Soil and gravel	10	5
	1.	Coarse brown sandstone	4	0
	2.	Light coloured and buff shale	9	0
		Red sandstone	3	0
		Light-blue shale	2	9
		Red sandy clay	14	3
		Variegated clay	13	0
		Dark shale	21	7
			78	0

This boring was in progress when I had to leave at the end of May, and I have not yet received accounts of its completion. The enormous thickness of shale recalls the section in No. 7, and both sections may possibly be below the white sandstone which underlies the coal. But it is more probable that the shale represents the shale and coal found in the two first boreholes.

Lastly, as the absence of coal had been proved to the north-east and west, and no borings had been found practicable to the east, while the ground to the south appear-

ed equally unfavourable for boring, except at a place on the bed in the Godávarí, where operations might at any moment, at the season now reached (June), have been stopped by a rise in the river, a borehole was recommended 500 yards south of No. 8 and south-south-west of No. 1. This (No. 9) has given the following section, sent to me by Mr. Vanstavern since my arrival in Calcutta--

			Ft.	In.
(No. 9).		Soil, &c.	39	0
	1.	Brown sandstone and conglomerate	23	0
	2.	Dark shale	3	0
		Ironstone	2	6
		Shale	2	0
		Coal	1	6
		Shale	2	0
		Coal	2	1
		Shale, carbonaceous	2	0
		Coal	1	6
		Shale, carbonaceous	1	6
		Coal	1	6
		Shale, carbonaceous	1	0
		Coal	1	0
		Shale, carbonaceous	2	0
		Coal	1	0
		Shale, carbonaceous	1	0
		Coal	2	0
		Shale	23	0
			112	7

The section is remarkably like that at No. 2. It decidedly strengthens the evidence in favour of all the boreholes having passed through the continuation of the same beds, for we have in this case a great thickness of shale as in Nos. 7 and 8, with the coal as in No. 2. The total thickness of coal as yet proved in this last borehole is 10 feet 7 inches.

To sum up the evidence: the presence of coal has been proved over a small area which contains probably 25,000 tons, or rather more, of which quantity it is as well not to assume that more than one-half can be profitably extracted, owing to the great admixture of shale. It is probable that the seam may be traced for some distance to the south, because the amount of coal, so far as is known, increases in that direction but it is hardly likely that a seam which thins out and disappears within so short a distance as 200 yards can be depended upon for any long distance. The quality has not yet been accurately ascertained. If, on cutting into the coal, it is found to burn fairly, a considerable quantity may be extracted, far more than sufficient to well repay

the expenditure incurred in boring, but, except in the improbable case of the coal continuing for a distance to the south and east, no permanent supply can be depended upon from this locality. The great admixture of shale and the variation in the seam will render it necessary to mine a large quantity of useless rock, and this will increase the cost of the coal, but in a country where no other supply exists, this alone should not prevent the coal being worked.

The locality is most favourable. The river is within half a mile when full, and about a mile during the dry season, and so soon as the coast canals are completed, it will be in constant water communication with Madras.

In conclusion, I would recommend that the remainder of this small tract of coal-bearing beds be thoroughly explored, as, even if no extensive seam of coal be found, a considerable quantity of useful fuel might be discovered, which would be available on an emergency. North of the river a borehole should be put down below the high bank at Rajgúmpa, at a spot where conglomerate is seen in the river bed, in order to test if the coal continues so far to the south-east. A boring might also be made where sandstone occurs in the stream north-east of Gaoriopeta, and another south of the large tank near Egerpeta, west of Tátpali, and one of the boreholes already sunk for preference No. 1, should be continued until the metamorphics or Tálchirs are reached. There is little chance of good from any further exploration on the north bank. On the south or right side of the river, the series of borings planned west of Madaváram should be carried out. The small breaks in the section near Amraváram might be explored in the same manner, and especially a spot above the mouth of the large stream which enters the Godávarí just above the village, as small fragments of shale and coal are hereabouts scattered along the edge of the river, and may indicate a coal seam below the sandstone exposed at a place where there are some bushes beneath the bank.

If all endeavours to find a permanent coal supply in this locality fail, an eventuality for which we must be prepared, the next chance is near Lingálá. Here I consider further exploration in British territory as almost hopeless, the Tálchirs must crop out everywhere below the mouth of the Tál close to the river bank, so that the Damúdás are confined, or nearly so, to the bed of the river and the country on the opposite side. Above the mouth of the Tál for some distance it is simply impossible to say what exists, for the whole country is covered with thick alluvium as far as Cherla, where the only rocks that are known to occur appear to me undoubtedly Kámthís, and all the Damúdás and Tálchirs are overlapped. The only plan by which any good can be done is an exploration of all the breaks in the section exposed above the top of the Tálchirs at Sangáram on the right bank of the river in the same manner as I have recommended

near Madaváram. The dip varies from 10° to about 20°, and the depth to which the boring in each case must be sunk will be found by multiplying the length of the break by the tangent of the angle of dip.

I am under great obligation to Mr. Vanstavern for the very thorough manner in which he has aided me, and for his readiness to carry out every suggestion I made. Mr. Heppel's services in charge of the boreholes were invaluable; it is mainly due to his thorough knowledge of boring and to his hard work, in an intensely hot season and despite many difficulties, that so much has been accomplished in a short time.

CALCUTTA,
July 6th, 1871.

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